

GIS and Remote Sensing: New Trends in Feature and Object Recognition

Jeff Thurston
March 2002

Background

Feature recognition is of primary importance to GIS users. It is through the determination of patterns and objects that surfaces are delineated and classified. These patterns and objects are then used to later build GIS topology useful for analysis, modeling, map making or used to create visualizations. Images may be acquired through various platforms including aerial photographs, satellite imagery and radar. These images contain grids of pixels from surfaces that may be evaluated, based upon their level of reflected radiation. Those values are dependent upon reflection, transmission and scattering of solar illumination and the reflected values are assigned numbers ranging from 0 to 255 – sometimes called bit ranges. For active radar applications, a directed microwave beam is emitted toward a surface and the reflected radiation ascertained. Radar is not dependent upon solar radiation for creating images. Pattern analysis is used to determine patterns and objects through the evaluation of individual pixels and their relationship to each other. This can be achieved subjectively which is very tedious or it may be automated. In this article we will discuss some of the techniques and considerations when determining patterns and objects from imagery and also look at some of the newer techniques being used for pattern and object recognition.

Image Classification

Pixels must be classified using defined criteria, evaluating the values for pixels that are related to surface patterns and objects. If knowledge about the surface is known and pixel evaluation proceeds, referring to that knowledge, this then is referred to as ‘supervised classification’ as compared to ‘unsupervised classification’ which evaluates individual pixels based upon readily recognized patterns and objects. A distinction is made between those values, which are classed as compared to those values that truly represent patterns and objects. In other words, similar objects may have differing pixel values but the relationships of those values form ‘signatures’. Studying the relationships of signatures begins the process of delineating patterns and identifying objects – each signature



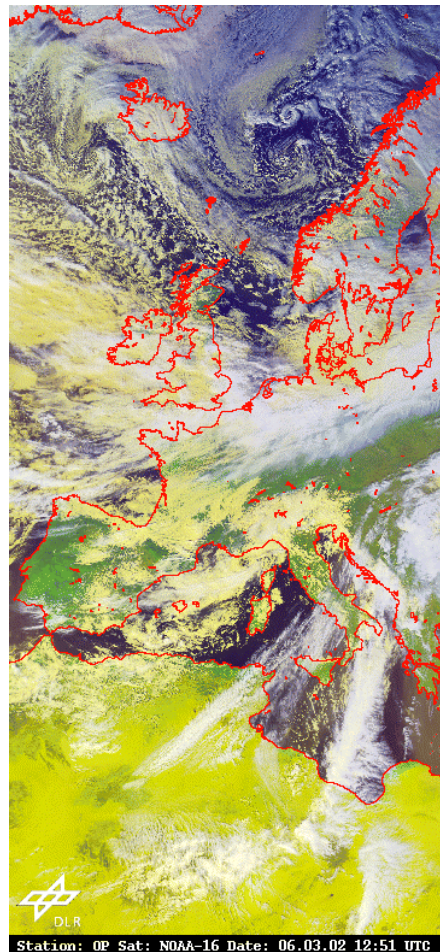
Courtesy – DIGITALGLOBE
QuickBird – Washington, D.C.

becomes a class. ‘Parametric signatures’ are signatures derived through statistical classification of the pixels (i.e. average, maximum likelihood, variance). ‘Non-parametric signatures’ – thus classification, is based upon objects that are discrete in nature, for example, a building, road, river or mountain. In short, objects become identified by firstly generating parametric signatures using pixel statistics, then applying those statistics to determine non-parametric signatures – or object identification.

This sounds simple enough but current statistical methods of image classification do not involve a more robust understanding or ‘*knowledge*’ of the image useful for classification. Consider a pixel obtained from for an (10 m²) area on a remotely sensed image. That pixel is subject to absorption of solar radiation, scattering to the sides as well as reflectance back to the sensor. Clearly, one pixel (area) can and does affect those around it, particularly through scattering (Townshend, 2000). These affects are termed ‘mixed pixel’ relationships. Consequently this pixel mixing contributes to the difficulty of determining objects and patterns using statistical based techniques – the impacts of nearby surfaces potentially affecting each pixel significantly. Statistical methods for pixel evaluation are without a doubt the most prominent method currently employed today for classifying images around the world and remain a valuable method for image classification. But, what if another approach was taken? What if we used other methods incorporating knowledge based reasoning?

The Issue of Boundaries

Boundaries may be very clear and easy to determine for some objects but for others the boundaries are indeterminate and are often fuzzy and some phenomenon might overlap. Soils, water quality, incidence of disease, fire intensity, pavement condition and ecological zones are good examples of entities that often do not have distinct sharp boundaries. Pixel values for these areas tend to vary due to the fact that they do not necessarily occur as homogenous representations – all forests are not pure pine, beech or oak. They may be mixed wood stands of varying compositions of species. Alternatively, delineating soil types may also have numerous areas with indeterminate boundaries. Soil does not have sharp boundaries and mixing occurs between types, varies with slope and varies with vegetation. These non-homogenous phenomenon will have varying reflectance patterns. When speaking about boundaries, one method increasingly being used for segmenting boundaries is ‘fractal net



Station: OP Sat: NOAA-16 Date: 06.03.02 12:51 UTC

Courtesy: DLR – German Space Center
AVHRR

evolution approach' (Batz and Shape, 2000). This approach looks at pixel regions as objects, evaluating them within the context of reality. The advent of new satellite platforms makes this increasingly possible due to higher image resolution because objects can be more clearly identified. But while improved, there are still problems in segmenting images. Approaches that couple other knowledge-based elements are providing a means to more accurately delineate patterns and objects.

What is Logical Anyhow?

The word 'logical' is used in GIS when we are referring to the integrity of the data set with respect to its character. Logical consistency considers, for example, that road networks are connected, one street leading to another and another. However, they may end where there is a dead-end street or a driveway approaches a house. Rivers do not have breaks in them usually, but are continuous and usually flow downhill not uphill. Most buildings (in general) have straight lines / edges, rise in elevation from the ground surface and tend to be square or perhaps rectangular in shape. But, objects on the landscape may also have texture. Trees have coarser texture than man-made constructions. Lakes will be flat and smooth while mountains will be rough. Similar to photogrammetry interpretation where texture is employed, remote sensing analysis is breaking new ground through the evaluation of texture. The classification of satellite



Courtesy NASA: LandSAT 7 – Santa Barbara, California

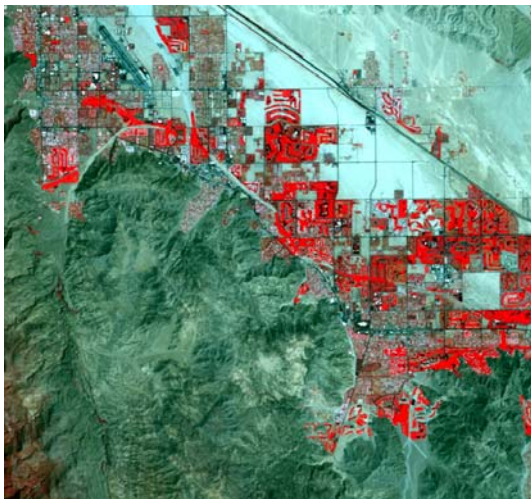
images by studying the relationship of pixel texture to pixel values as well as height opens the door to provide a framework for the identification of patterns and objects more accurately – and automatically. Ultimately though, classifications based upon texture, shape, color and height must be able to generate topology that can be imported into a GIS. For that they must construct a database. Therefore as objects and patterns are recognized, new topology is built and thematic layers created. The key to this form of segmentation is looking at not one or two pixels but at groups of pixels, their arrangement collectively then analyzing those patterns. Techniques being used for this are fractal geometry and fuzzy logic.

Imagine there is a line of pixels on an image. These pixels then branch to other pixels of similar value rising up a hill, then suddenly turn halfway up and go back down the hill

only to return uphill again and branching further. Obviously they cannot represent a river because rivers do not flow up and down hills. Logically then these pixels represent a road or maybe electrical lines. But, suddenly you notice other groups of pixels of similar values in patterns and they appear to be square in shape. These are probably houses in a neighborhood. Closer inspection reveals that the lines appear between these square collections of objects. The question still remains – are they roads or electrical lines? Roads and electrical lines could be expected to occur in both cases, however, one does not normally expect to find electrical lines equidistant between the square objects – they are either on one side of the street or the other. Using this example we have taken patterns of pixel values for the lines, determined square objects based on their patterns and shape, incorporated knowledge of river flow with respect to terrain and added some thoughts about how electrical utilities are placed within neighborhoods. A multiple approach involving reason and knowledge has been applied. Topology is then drawn and a new layer created which is automatically labeled by object type.

Value for GIS

A remotely sensed image must first be classified accurately for later GIS use. For a raster model, gridded pixels will represent patterns and objects. If the remotely sensed image is classified using these techniques then represented using a raster topology, it defeats the purpose of the recognition in the first place, unless of course each pixel represents a very small area. Using a vector topology and the use of these segmentation techniques will



Courtesy NASA – LandSAT 7
Thule Air Force Base, Greenland.

more accurately represent each classification. The value is in being able to automatically generate topology based upon patterns and objects presented. In practice people sometimes approach each new remote sensing project from the start, delineating whole areas to construct their maps – essentially re-mapping areas. This does not have to be the case. Often some objects and patterns for areas have been classified previously. If already existing classifications (thematic layers) are present they could be coupled to segmentation procedures, speeding up the process while being used as references. In other words – why re-invent in the wheel? By incorporating already existing data into

these methods, slowly databases are built while refining the segmentation criteria used to identify and classify objects and patterns. This approach has major benefits for regions where similar patterns and objects – and phenomenon occur. Therefore libraries for pattern recognition and objects can be built through which algorithms for future analysis are constructed.

Applications and Use

The process of analyzing remotely sensed images is often time consuming. In certain emergency applications, requiring quick automatic feature and object recognition these methods could be useful for decision making purposes. Most remotely sensed images are periodic and do not occur continuously so this factor must be taken into account. But these techniques are not restricted to satellite imagery but may also be applied to aerial photographs, LIDAR and digitally captured images from cameras where object recognition and pattern identification are important.

Forestry applications are good candidates for these applications due to the fact that much data already exists, like forest inventory and DEM that can be readily incorporated. Urban applications may already been in use that have road network and existing housing delineated. The concept of identifying objects and patterns is more directly applicable to identifying change over time. This does not mean that already existing datasets need already be available, only that existing objects and patterns or 'the knowledge base' and having access to them provides the means to initiate coupling them to the methods quicker for applications.

Summary

Trends for image segmentation for satellite, aerial photograph and LIDAR data involve use of a multiple-approach coupling image shapes, color, texture, knowledge and existing data such as DEM for the purposes of identifying patterns and objects. These methods provide a means to quickly and automatically classify images. New data and themes can be generated for GIS in a consistent manner allowing for use in numerous applications that involve classification for initial analysis or for the purpose of monitoring change over time. These applications include agriculture, forestry, urban applications and emergency applications.

Additional Information:

[Canada Center for Remote Sensing](#) – Road detection

[Cartographic Feature Extraction](#) – George Vosselman

[CSIRO – Mathematical and Information Sciences](#)

[Definiens AG - ecognition](#)

[GENIE](#)

[Hitachi - FeatureXTR](#)

[PCI Geomatics - APEX](#)

[U.S. Department of Transportation](#) – Automatic Feature Extraction

References

Batz, M. and Shape, A. 2000. Multi-resolution Segmentation – an optimization approach for high quality multi-scale image segmentation. In: Strobl, J., Blaschke, T., Griesebner, G. (eds): *Angewandte Geographische Informationsverarbeitung XII*, Wichmann Verlag, Heidelberg. pp. 12-23.

Townshend, J. et al, 2000. Beware of per pixel characterization of land cover. *Journal of Remote Sensing*.(4) pp. 839-843.

Jeff Thurston – is European Director for Integral GIS and based in Berlin, Germany. He has a MSc. in Geographic Information Systems and is a graduate of UNIGIS Vancouver, British Columbia, Canada. Jeff specializes in integrated geo-technology applications and visualization and writes for several publications internationally.