REMOTE SENSING AND ITS APPLICATIONS IN GEOGRAPHY - 18MAG24E

(Syllabus - UNIT – IV: Image processing: Pre-processing: Rectification and Enhancements – Manipulation - Classification methods: Supervised and Unsupervised - Ground truth verification – Accuracy assessment -Vegetation Indices: VI and NDVI, Software**:** ERDA and ENVIS..)

Digital Image Processing

As a result of solid state multispectral scanners and other raster input devices, we now have available digital raster images of spectral reflectance data. The chief advantage of having these data in digital form is that they allow us to apply computer analysis techniques to the image data—a field of study called Digital Image Processing.Digital Image Processing is largely concerned with four basic operations: image restoration, image enhancement, image classification, image transformation.

Image restoration is concerned with the correction and calibration of images in order to achieve as faithful a representation of the earth surface as possible—a fundamental consideration for all applications. Image enhancement is predominantly concerned with the modification of images to optimize their appearance to the visual system. Visual analysis is a key element, even in digital image processing, and the effects of these techniques can be dramatic. Image classification refers to the computer-assisted interpretation of images—an operation that is vital to GIS. Finally, image transformation refers to the derivation of new imagery as a result of some mathematical treatment of the raw image bands. In order to undertake the operations listed in this section, it is necessary to have access to Image Processing software.

Image Restoration

Remotely sensed images of the environment are typically taken at a great distance from the earth's surface. As a result,there is a substantial atmospheric path that electromagnetic energy must pass through before it reaches the sensor.Depending upon the wavelengths involved and atmospheric conditions (such as particulate matter, moisture content andturbulence), the incoming energy may be substantially modified. The sensor itself may then modify the character of thatdata since it may combine a variety of mechanical, optical and electrical components that serve to modify or mask themeasured radiant energy. In addition, during the time the image is being scanned, the satellite is following a path that issubject to minor variations at the same time that the earth is moving underneath. The geometry of the image is thus inconstant flux. Finally, the signal needs to be telemetered back to earth, and subsequently received and processed to yieldthe final data we receive. Consequently, a variety of systematic and apparently random disturbances can combine todegrade the quality of the image we finally receive. Image restoration seeks to remove these degradation effects.Broadly, image restoration can be broken down into the two sub-areas of radiometric restoration and geometric restoration.

Radiometric Restoration

Radiometric restoration refers to the removal or diminishment of distortions in the degree of electromagnetic energy reg-istered by each detector. A variety of agents can cause distortion in the values recorded for image cells. Some of the mostcommon distortions for which correction procedures exist include:uniformly elevated values, due to atmospheric haze, which preferentially scatters short wavelength bands (particularly the blue wavelengths);striping, due to detectors going out of calibration; random noise, due to unpredictable and unsystematic performance of the sensor or transmission of the data; and scan line drop out, due to signal loss from specific detectors. It is also appropriate to include here procedures that are used to convert the raw, unit less relative reflectance values (known as digital numbers, or DN) of the original bands into true measures of reflective power (radiance).

Geometric Restoration

For mapping purposes, it is essential that any form of remotely sensed imagery be accurately registered to the proposed map base. With satellite imagery, the very high altitude of the sensing platform results in minimal image displacements due to relief. As a result, registration can usually be achieved through the use of a systematic rubber sheet transformation process10 that gently warps an image (through the use of polynomial equations) based on the known positions of a set of widely dispersed control points. This capability is provided in IDRISI through the module RESAMPLE. With aerial photographs, however, the process is more complex.

Not only are there systematic distortions related to tilt and varying altitude, but variable topographic relief leads to very irregular distortions (differential parallax) that cannot be removed through a rubber sheet transformation procedure. In these instances, it is necessary to use photogrammetric rectification to remove these distortions and provide accurate map measurements11. Failing this, the central portions of high altitude photographs can be resampled with some success. RESAMPLE is a module of major importance, and it is essential that one learn to use it effectively. Doing so also requires a thorough understanding of reference systems and their associated parameters such as datum's and projections. The chapter on Georeferencing later in this volume provides an in-depth discussion of these issues.

Image Enhancement Image enhancement is concerned with the modification of images to make them more suited to the capabilities of human vision. Regardless of the extent of digital intervention, visual analysis invariably plays a very strong role in all aspects of remote sensing. While the range of image enhancement techniques is broad, the following fundamental issues form the backbone of this area:

Contrast Stretch

Digital sensors have a wide range of output values to accommodate the strongly varying reflectance values that can be found in different environments. However, in any single environment, it is often the case that only a narrow range of values will occur over most areas. Grey level distributions thus tend to be very skewed. Contrast manipulation procedures are thus essential to most visual analyses.

Composite Generation

For visual analysis, color composites make fullest use of the capabilities of the human eye. Depending upon the graphics system in use, composite generation ranges from simply selecting the bands to use, to more involved procedures of bandcombination and associated contrast stretch.

Digital Filtering

One of the most intriguing capabilities of digital analysis is the ability to apply digital filters. Filters can be used to provide edge enhancement (sometimes called crispening), to remove image blur, and to isolate lineaments and directional trends, to mention just a few. The IDRISI module FILTER is used to apply standard filters and to construct and apply user-defined filters.

Image Classification

Image classification refers to the computer-assisted interpretation of remotely sensed images. Although some procedures are able to incorporate information about such image characteristics as texture and context, the majority of image classification is based solely on the detection of the spectral signatures (i.e., spectral response patterns) of land cover classes. The success with which this can be done will depend on two things: 1) the presence of distinctive signatures for the land cover classes of interest in the band set being used; and 2) the ability to reliably distinguish these signatures from other spectral response patterns that may be present. There are two general approaches to image classification: supervised and unsupervised. They differ in how the classification is performed. In the case of supervised classification, the software system delineates specific landcover types based on statistical characterization data drawn from known examples in the image (known as training sites). With unsupervised classification, however, clustering software is used to uncover the commonly occurring land cover types, with the analyst providing interpretations of those cover types at a later stage.

Supervised Classification

The first step in supervised classification is to identify examples of the information classes (i.e., land cover types) of interest in the image. These are called training sites. The software system is then used to develop a statistical characterization of the reflectances for each information class. This stage is often called signature analysis and may involve developing a characterization as simple as the mean or the range of reflectance on each band, or as complex as detailed analyses of the mean, variances and covariances over all bands. Once a statistical characterization has been achieved for each information class, the image is then classified by examining the reflectances for each pixel and making a decision about which of the signatures it resembles most. There are several techniques for making these decisions, called classifiers. Most Image Processing software will offer several, based on varying decision rules.

Unsupervised Classification

In contrast to supervised classification, where we tell the system about the character (i.e., signature) of the information classes we are looking for, unsupervised classification requires no advance information about the classes of interest. Rather, it examines the data and breaks it into the most prevalent natural spectral groupings, or clusters, present in the data. The analyst then identifies these clusters as landcover classes through a combination of familiarity with the region and ground truth visits.

It is important to recognize, however, that the clusters unsupervised classification produces are not information classes, but spectral classes (i.e., they group together features (pixels) with similar reflectance patterns). It is thus usually the case that the analyst needs to reclassify spectral classes into information classes.

For example, the system might identify classes for asphalt and cement which the analyst might later group together, creating an information class called pavement. While attractive conceptually, unsupervised classification has traditionally been hampered by very slow algorithms. With suitable ground truth and accuracy assessment procedures, this tool can provide a remarkably rapid means of producing quality land cover data on a continuing basis.

Ground truth and the collection of ground-truth data on location enables calibration of remote-sensing data, and aids in the interpretation and analysis of what is being sensed.

The field collection of reflectance spectra of in-place materials (often referred to as ground truthing data collection) is essential for interpreting unknown materials in multi-spectral and hyperspectral remote sensing data, and validating sensor performance. Since sample removal for lab study often destroys the sample’s surface properties, and because lab study is impractical for many large natural surfaces, researchers need a reliable field device capable of providing laboratory-quality, field measurements with illumination and viewing geometry equivalent to a satellite or aircraft sensor.

Such ground truthing devices can also provide data for radiometric and atmospheric correction of satellite images. This requires field reflectance measurements of large test panels or large, uniform surfaces such as dry lake beds. As with ground surfaces, it is essential that researchers measure these targets with illumination and viewing geometry equivalent to that of the imaging sensor of interest.

Accuracy Assessment

A vital step in the classification process, whether supervised or unsupervised, is the assessment of the accuracy of the final images produced. This involves identifying a set of sample locations that are visited in the field. The land cover found in the field is then compared to that which was mapped in the image for the same location. Statistical assessments of accuracy may then be derived for the entire study area, as well as for individual classes.

Image Transformation

Digital Image Processing offers a limitless range of possible transformations on remotely sensed data. Two are mentioned here specifically, because of their special significance in environmental monitoring applications.

Vegetation Indices

There are a variety of vegetation indices that have been developed to help in the monitoring of vegetation. Most are based on the very different interactions between vegetation and electromagnetic energy in the red and near-infrared wavelengths.

he NDVI is calculated from these individual measurements as follows:

$$\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})}$$

where Red and NIR stand for the spectral reflectance measurements acquired in the red (visible) and near-infrared regions, respectively. These spectral reflectances are themselves ratios of the reflected over the incoming radiation in each spectral band individually, hence they take on values between 0.0 and 1.0. By design, the NDVI itself thus varies between -1.0 and +1.0. NDVI is functionally, but not linearly, equivalent to the simple infrared/red ratio (NIR/VIS). The advantage of NDVI over a simple infrared/red ratio is therefore generally limited to any possible linearity of its functional relationship with vegetation properties (e.g. biomass). The simple ratio (unlike NDVI) is always positive, which may have practical advantages, but it also has a mathematically infinite range (0 to infinity), which can be a practical disadvantage as compared to NDVI. Also in this regard, note that the VIS term in the numerator of NDVI only scales the result, thereby creating negative values. NDVI is functionally and linearly equivalent to the ratio NIR / (NIR+VIS), which ranges from 0 to 1 and is thus never negative nor limitless in range. But the most important concept in the understanding of the NDVI algebraic formula is that, despite its name, it is a transformation of a spectral ratio (NIR/VIS), and it has no functional relationship to a spectral difference (NIR-VIS).

Principal Components Analysis

Principal Components Analysis (PCA) is a linear transformation technique related to Factor Analysis. Given a set of image bands, PCA produces a new set of images, known as components, that are uncorrelated with one another and are ordered in terms of the amount of variance they explain from the original band set.

PCA has traditionally been used in remote sensing as a means of data compaction. For a typical multispectral image band set, it is common to find that the first two or three components are able to explain virtually all of the original variability in reflectance values. Later components thus tend to be dominated by noise effects. By rejecting these later components, the volume of data is reduced with no appreciable loss of information.

Erdas Imagine

Erdas Imagine is an image processing software package that allows users to process both geospatial and other imagery as well as vector data. Erdas can also handle hyperspectral imagery and LiDAR from various sensors. Erdas also offers a 3D viewing module (VirtualGIS) and a vector module for modeling. The native programming language is EML (Erdas Macro Language). Erdas is integrated within other GIS and remote sensing applications and the storage format for the imagery can be read in many other applications (*.img files). Leica Geosystems also purchased ER Mapper to add to their mapping software. Imagine is tightly woven into the GIS fabric more than other image processing software packages and that is the advantage of this package.

ENVI image analysis software

ENVI image analysis software is used by GIS professionals, remote sensing scientists, and image analysts to extract meaningful information from imagery to make better decisions. ENVI can be deployed and accessed from the desktop, in the cloud, and on mobile devices, and can be customized through an API to meet specific project requirements."

ENVI is designed to be used by anyone who relies on imagery and data to make decisions. It delivers expert-level results across the board, regardless of a user's prior experience with imagery.

ENVI is a flexible solution that can be customized to meet specific project needs and can be deployed and accessed from the desktop, in the cloud, and on mobile devices. Fully integrated with ArcGIS for Desktop and ArcGIS for Server from Esri, users can access ENVI tools directly within the Arc environment to add image analysis capabilities to their GIS models and applications.

ENVI supports imagery from today's newest and most popular satellite and airborne sensors, including multispectral, hyperspectral, panchromatic, LiDAR, infrared, thermal, radar, HDF5, full-motion video, LAZ, ASCII, and NET CDF-4. ENVI includes a comprehensive suite of image analysis tools that allowing customers to access proven algorithms to quickly, easily, and accurately analyze imagery.

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