Generation and interpretation of images

Montesinos S., Fernández L.

in

Erena M. (coord.), López-Francos A. (coord.), Montesinos S. (coord.), Berthoumieu J.-P. (coord.).
The use of remote sensing and geographic information systems for irrigation management in Southwest Europe

Zaragoza : CIHEAM / IMIDA / SUDOE Interreg IVB (EU-ERDF)
Options Méditerranéennes : Série B. Etudes et Recherches; n. 67

2012
pages 31-36

Generation and interpretation of images

S. Montesinos and L. Fernández

GEOSYS S.L., Sector Foresta 23, locales 7 y 8, 28760 Tres Cantos, Madrid (Spain)

Abstract. A digital image is a representation of a real object using a numerical two-dimensional matrix where each element is called pixel. The digital process is the set of numerical transformations performed on the original matrix to obtain more appropriate representations of the image, depending on applications. Restoration processes are aimed to eliminate the radiometric errors sounds and geometric distortions generated during the compilation and transmission of data. The highlight consists on a set of techniques to improve the visual interpretation of the image. The multitemporal and multiespectral character of remote sensing data allows transformations that produce new components or bands of the image.

Keywords. Digital image processing – Restoration – Highlight – Information extraction.

La génération et l'interprétation des images

Résumé. *Une image numérique est une représentation d'un object réel en utilisant un tableau numérique à deux dimensions où chaque élément du tableau est appelé pixel. Des processus numériques sur la matrice d'origine sont utilisés pour obtenir des représentations appropriées de l'image, en fonction des applications. Les processus de restauration visent à éliminer les erreurs radiométrique et géometrique et de bruit générées lors de la compilation et la transmission de données. Le point culminant est un ensemble de techniques visant à améliorer l'interprétation des images visuelles. Le caractère multi-temporelle et multispectrale des données de télédétection permet des transformations qui produisent de nouveaux composants ou des bandes de'image.*

Mots-clés. *Traitement d'image numérique – Restauration – Amélioration –Extraction de l'information.*

I – Introduction

It is possible to carry out different types of analysis of images depending on data media. If the available data are of analogue nature, in black or white or in colour, a photo-interpretation is performed according to similar criteria used for aerial photography, its means depending on colour function, tone, texture, etc. If data are available in digital media, we can perform a spatial analysis based on digital image processing, which consist on a set of numerical transformations performed over the original data to obtain representations more appropriate of the image depending on future applications.

II – Overview of digital image processing

A *digital image* is a representation of a real object using a numerical bi-dimensional matrix where each element of matrix is called pixel. Each pixel has assigned a digital value that represents the associated energy with the range of wavelengths within sensibility of the detector. Thus, the measured proprieties are converted from a continuous range of values to a range expressed by a finite integer numbers that are recorded in a byte or binary code (2^8 values, from 0 to 255). The position of the pixels in an image is determinate by a coordinate system in (x,y) with the origin in the upper left corner (Fig. 1).

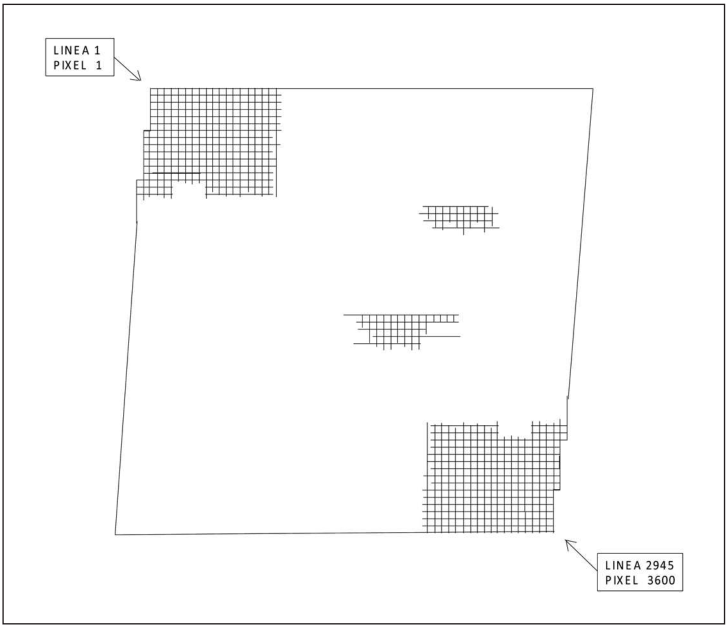

Fig. 1. Arrangement of pixels in a quarter of Landsat TM scene.

The *digital process* is the set of numerical transformations performed on the original matrix to obtain more appropriate representations of the image, depending on the applications.

In general, digital image processing can be divided into three parts:

(i) Image Restoring: Radiometric correction; Geometric correction.

(ii) Image Enhancement: Radiometric enhancement; Geometric enhancement.

(iii) Information Extraction: Main components, Arithmetic; Multispectral classifications.

The mathematical basis of the image process can be found in Dainty and Shaw (1976), Rosenfeld and Kak (1976), Andrews and Hunt (1977), Pratt (1978) and Gaskill (1978).

III – Image restoring

When sensors aboard satellites capture an image, errors can be caused in the geometry and radiometric values assigned to pixels. Restoration process are aimed to eliminate radiometric errors, as well as noise and geometrical distortions generated during the capture and transmission of the data.

The origins of radiometric errors are:

(i) The atmosphere effect on the electromagnetic radiation: the atmosphere disperses selectively the electromagnetic radiations according to their wavelength. In general, the visible bands used to be affected much more infrared bands. This leads to a loss in the calibration of the radiometric values associated with a specific pixel.

(ii) Errors of instrumentation: mainly due to the design and operating mode of the sensor. The most widespread of these errors is due to detectors.

Radiometric correction is performed by mathematical algorithms that relate the digital values of pixels in each band, providing the real reflectance of field (RICHARDS, 1986). Developments of these algorithms can be found in Turner and Spencer (1972), Slater (1980) and Foster (1984).

The origin of geometrical distortions is due to several factors (Fig. 2):

(i) The Earth's rotation during image acquisition.

(ii) Panoramic distortion due to scanner.

(iii) Skewness in the sweep.

(iv) Variations in the mirror speed.

(v) Variations in the altitude, attitude and speed of the spectral platform.

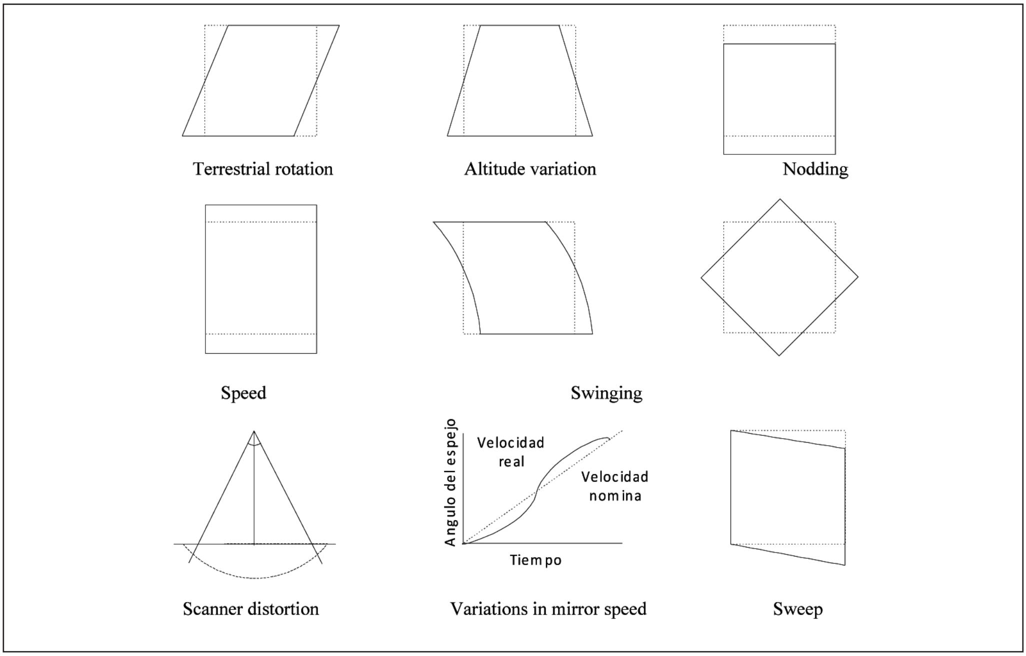

Fig. 2. Geometrical distortions of satellite images.

IV – Enhancement of the image

The enhancement is a set of techniques to improve the interpretation of the image. It can be radiometric or geometric. Radiometric enhancement modifies the pixel individually, increasing the contrast of the image. Geometric enhancement involves a spatial improvement, because digital pixel values are changed using the value of the surrounding pixels.

Colour composition, as an example, is one of the methods able to enhance digital images, because human eye only is capable to distinguish 30 levels of grey, spite is very sensible to colour (Fink, 1976; Shepard, 1969; Drury,1987).

A satellite scene is defined by the histogram. If each image pixel is examinated, it is possible to construct a graphic which represent the number of pixels with a specified value over a range of values. The histogram of an image can also be seen as a discrete distribution of probability, because the relative height of each bar represents the statistical probability of finding a particular digital image value (Fig. 3).

Tonal or radiometric quality o fan image can be determinate from its histogram, because an image that cover the full range of digital values Hill not present accumulation of frequencies in at the ends.

An image has only one histogram, although exist the possibility that the same histogram represent several images. The histogram indicates the contrast and homogeneity of the scene.

Associated with this idea is the concept of cumulative histogram (Fig. 3) representing the threshold value of the image in relation to the total number of pixel. It is a continuous function of the value change within the image.

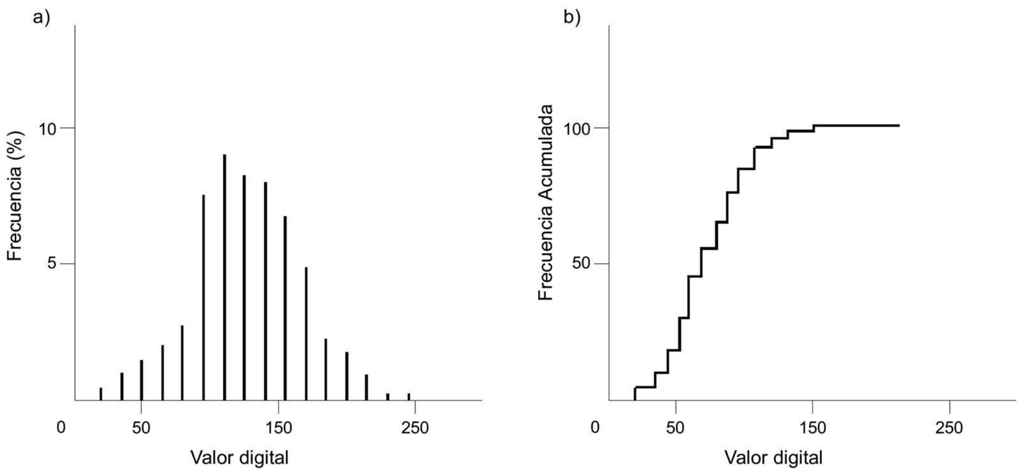

Fig. 3. (a) Original histogram; (b) Cumulative histogram.

Radiometric enhancement techniques more commonly used are:

(i) Amendment of contrast.

(ii) Histogram equalization.

(iii) Density slicing.

Geometric enhancement techniques consist in the implementation of filters, where the pixel value will be recalculated based on pixels around it. These filters are used to soften the noise of the image and to detect edges and lines.

We must keep in mind that enhancements can not be used until the other treatments are completed, as they distort the original values of pixels (Soha *et al.*, 1976).

V – Information extraction

Multitemporal and multispectral character of remote sensing data allows transformations that produce new components or bands in the image. These components are an alternative and different representation of collected data in the image. The relationship between new and old values is done by means of linear operations. Among the most important and widespread techniques to extract information, the following are included:

(i) The *principal component analysis*: The information provided by various bands of a sensor use to be redundant within a range of wavelengths of the visible or infrared, so sometimes it is possible to omit some of them. An initial statistical analysis of the bands allows us to know:

– The mean and standard deviation of grey values for each band (frequency histograms)

– The correlation coefficients of bands.

– The variance-covariance matrix.

These variables indicate the additional information that each band bring to the image and the redundancy of data, allowing to eliminate all those that represent a high correlation, without involving a loss of information.

The principal component analysis consist then in the generation of a new set of spectral bands whose correlation is zero and the variance is maximum, meaning that previously information that was contained in "m" bands correlated each others (this implies redundancy in the contend information) now is expressed in "p" principal components, being "p<m".

(ii) *Arithmetic* between bands (addition, subtraction, multiplication and division): are performed on two or more images of the same area. These images may contain multispectral multiespectral (different bands) or multitemporal (various dates) information.

The addition is used to check if the dynamic range of an image is the same as the original ones or on the contrary is necessary to be rescaling. It is used to dampen noise.

Subtraction is used to highlight the different between images and is mainly used to detect changes between images of different dates.

Multiplication is performed between a spectral band and a matrix (mask) consisting on ones and zeros. Thus, pixel value multiplied by 0 becomes 0, and yet values multiplies by 1 keep its value. It is used when an image is form by several different areas as an example, a coastal zone where interest must be focus on sea or land. The mask will isolate this area doing zero the rest of the image.

Division or ratio between bands is one of the transformations more used in remote sensing. The reason why ratios bands are used can be summarized in two: correlation between ratio values and the shape of spectral reflectance curves between two wavelengths and the reduction of the topography effect.

iii) *Techniques of classification* are defined as the process of assignation of individual pixels of multispectral images to discrete categories of thematic category or information about radiometric values that best fit (Fig. 4).

There are two different techniques that often used to be complementary:

- Unsupervised classification: is the measure that image pixels are assigned to spectral classes without operator knows the nature of these classes. Algorithms used are clusters or groupins. These procedures are used to determinate the number and localization of spectral classes in which digital data can be divided. Operator can identify late the nature of these classes, with help of maps and field information.
- Supervised classification: In this case, operator specifies number of classes to be distinguished and statistical characteristics of each class. It is certain that the procedure more used is the quantitative analysis of remote sensing data. The different algorithms used are based on each spectral class can be described by a probabilistic distribution model in the multispectral space.

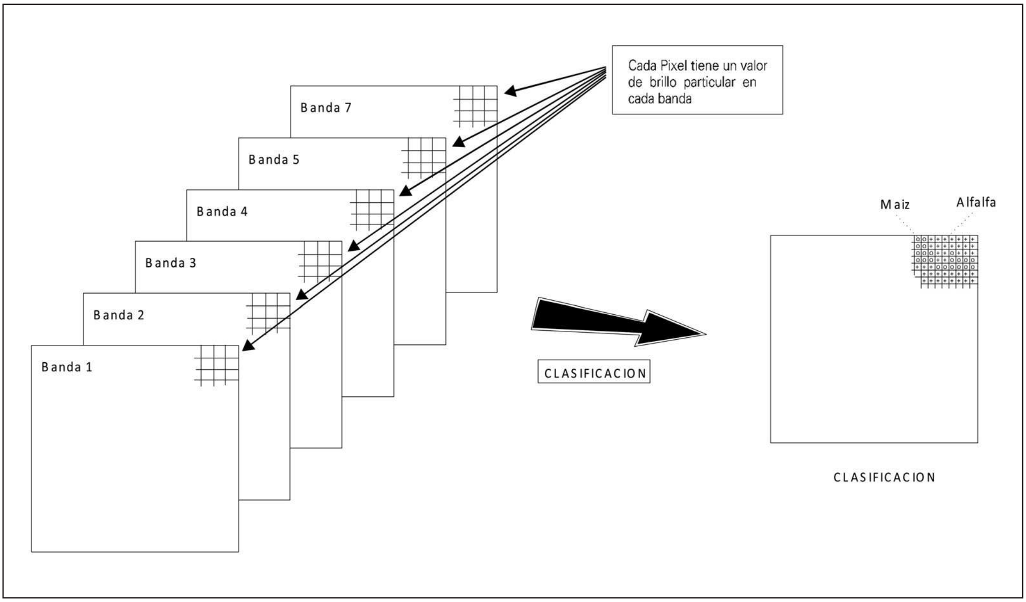

Fig. 4. Concept of automatic classification. Data correspond to 6 bands of reflexion bands of Thematic mapper sensor.

References

Andrews H.C. and Hunt B.R., 1977. *Digital image restoration*. Englewood Cliffs, N.J.: Prentice-Hall

Dainty J.C. and Shaw R., 1976. *Image Science*. Academic Press. New York.

Drury S.A., 1987. *Image Interpretation in Geology.* Allen & Unwin. London.

Fink W., 1976. Image coloration as an interpretation aid*. In: Proc. SPIE/OSA Conf. Image Process,* 74, p.209-215.

Foster B.C., 1984. Derivation of Atmospheric Correction Procedures for Landsat MSS with particular reference to urban data. In: *Int. Journal Remote Sensing*, 5, p. 799-817.

Gaskill J., 1978. *Linear systems, Fourier transforms and optics*. John Wiley and Sons. New York.

Pratt W.K., 1978. *Digital image processing*. John Wiley and Sons. New York.

Richards J.A., 1986. *Remote Sensing Digital Image Analysis. An Introduction*. Springer-Verlag. Berlin.

Rosenferd A. and Kak A.C., 1976. *Picture processing by computer*. Academic Press. New York.

Sheppard J.J., 1969. Pseudocolor as a means of image enhancement. In: *Am. J. Ophtalmo. Arch. Am. Acad. Optom.*, 46, p. 737-754.

Slater P.N., 1980. *Remote Sensing – Optics and Optical Systems*. Addison-Wesley. London.

Turner R.E. and Spencer M.H., 1972. Atmospheric Model for Correction of Spacecraft Data. In: *Proceedings 8th International Symposium on Remote Sensing of the Environment. Ann Arbor. Michigan*; p. 895-934.