# DEVELOPMENT OF AN INTEGRATED IMAGE PROCESSING AND GIS SOFTWARE FOR THE REMOTE SENSING COMMUNITY

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**Abstract**:

This paper describes the SPRING system, a comprehensive GIS and Remote Sensing Image Processing software package that has been developed by INPE and its partners and is available on the Internet, as freeware. SPRING contains functions for digital terrain modelling, spatial analysis based on vector and raster maps, database queries, and map production facilities, as well traditional and innovative image processing algorithms. The paper describes the SPRING system and examines the motivation behind the sharing of software for the remote sensing community over the Internet.

## 1. INTRODUCTION

One of the most important benefits of the Internet to the scientific and technical community has been the availability of software for research and teaching purposes, in many cases at no cost for the user. The use of freely available software not only enables the establishment of research laboratories at reduced cost, but also, most importantly, is a useful way of sharing technical and scientific results. Instead of just describing a new technique in a research report or paper, the entire algorithm can be made available to all interested parties, thereby effectively increasing the impact of the result.

At present, however, the remote sensing community, has limited options of freely available software. Therefore, we believe that there is a demand for a freely available software system that supports applications and research in the Remote Sensing and GIS areas. Based on these considerations, the Brazilian National Institute for Space Research (INPE) has been developing, since 1991, the SPRING system. The general objectives of SPRING project are:

- Support both raster and vector representations and *integration of remote sensing data into a GIS*, with functions for image processing, digital terrain modelling, spatial analysis and data base query and manipulation.

- Achieve *full scalability*, that is, be capable of working with full functionality from desktop PCs running Windows or Linux to high-performance UNIX workstations.

- Provide an easy-to-use, yet powerful environment, with a combination of menu-driven applications and a spatial algebra language, which provide a smooth learning curve.

This paper provides a general description of SPRING. Section 2 describes the system's object oriented data model. Section 3 provides a general view of the functions available, and Section 4 indicates some innovative results obtained in the Remote Sensing area. A more detailed description of SPRING is found in Câmara et al. (1996).

## 2 AN INTEGRATED DATA MODEL

In order to achieve the full integration of the GIS and Remote Sensing environments, SPRING's data model fully supports the two basic abstract representations of geographical reality: the *field model* and the *object model* (Worboys, 1995).

A field is formalized as a mathematical function whose domain is a region and whose range is the set of values taken by the field. Features such as topography, vegetation maps and LANDSAT images are modelled as fields. The *object model* represents the world as a surface occupied by discrete, identifiable entities, with a geometrical representation and descriptive attributes. Human-built features, such as roads and buildings, are typically modelled as objects.

The model used in SPRING has many benefits, including:

- The same abstract entity can be associated to different geometrical representations. For example, the same *thematic map* might be associated, in SPRING, to both a raster and a vector data structure.

- The design of an user interface which allows manipulation of geographical data at an abstract level. When a user selects data from one of the classes of the database schema, only the operations available for that specific data type are made available to him. This approach reduces, to a large extent, uncertainty in the choice of valid functions and brings down the learning curve.

For further discussion on SPRING's data model, please refer to Câmara et al. (1994) and

## 3 SYSTEM FUNCTIONALITY

### 3.1 Spatial Data Base Management

All the descriptive attributes of the geo-objects and geo-fields are stored on a data base management system. SPRING manages 12 cartographic projections. Facilities for data management, projection conversion, and raster and vector mosaicking images are available.

### 3.2 Data Entry

*Vector maps* can be digitised and edited on tablets or on the screen, with automatic creation of topological information. *Digital terrain models* can be created by digitising irregularly spaced points or by sampling contour lines, with support for both regular and triangular grids. *Remote sensing image* geocoding can be made by means of ground control point location, and images can be registered with maps or with other images. *Raster-to-vector* and *vector-to-raster* conversions enable the mapping between the available formats. SPRING also *imports* and *exports* data from a number of formats, including ARC/INFO, DXF, SPANS, TIFF, ERDAS, PCI, MaxiCAD and SGI/INPE.

### 3.3 Image Processing

Facilities for digital image processing include contrast enhancement, spatial filtering, radiometric correction, arithmetic operations, image statistics, maximum-likelihood (statistical) and region classifiers and a specific module for radar images. The main innovations on this area are described in section 4.

### 3.4 Geographical Analysis and Digital Terrain Modelling

SPRING includes a map algebra language, called LEGAL, which has *local, zonal and focal* operations. Map analysis can be performed by means of the LEGAL language or by using in-built functions, which include *calculation of area, perimeter, distances and angles, generation of buffer maps*. *Data base query* operations can be expressed in LEGAL or by means of an interactive interface. Digital terrain models (DTMs) are stored in *regular* and *triangular grids*, and can be shown as contour lines, grid point values and by 3D visualisation. DTMs can be analysed, including calculation of *slope* and *aspect maps*, and transformation into thematic maps or images.

### 3.5 Map Composition and Plotting

This module enables interactive map composition and plotting, with a WYSIWYG interface. The symbol library uses the DXF format, which enables easy addition by the user. Complete control over graphical elements is possible (size, position, colour and slant). Output devices supported include Postscript and HPGL/2, two standards widely accepted by the industry.

## 4. MAIN INNOVATIONS ON THE REMOTE SENSING AREA

This section describes some innovative results, which have been obtained as a result of research studies carried out at INPE. Altough these techniques have been the subject of intensive studies by the Remote Sensing community, they are not widely available in commercial systems.

### 4.1 Multispectral Region Classifier

Region classifiers have been shown to be an important alternative to traditional pixel-by-pixel classifier techniques. In SPRING, region classification is performed in two steps. Initially, the image is partitioned in regions of homogenous texture, by means of a segmentation algorithm, which is based on region-growing methods (Bins et al., 1996). The resulting regions are then classified, with two possible options:

- Region ISODATA: the clusters are obtained directly by an unsupervised technique, based on calculation of distances in the feature space, involving the mean and variance of each region.

- Supervised region classifier; the regions are classified, based on training samples indicated by the user, through the calculation of Battacharya distance between the regions

One of the great advantages of this technique is the homogeneity of the resulting image, without the non-classified outliers normally generated by a pixel classifier (Batista et al., 1995). Figure 2 illustrates the result of segmentation, in a LANDSAT TM image in Amazonia.

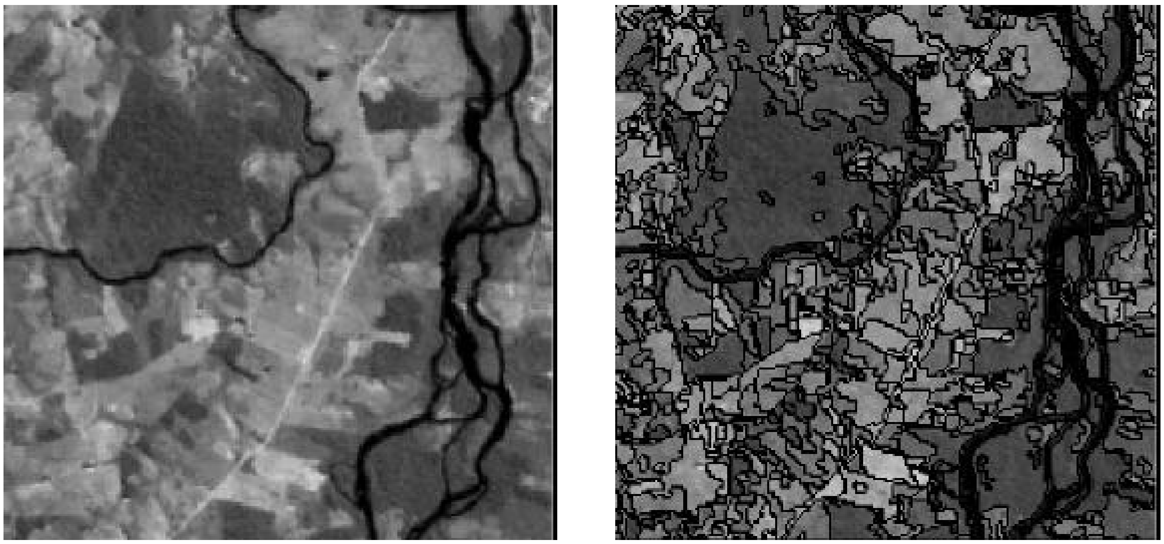

Figure 2. (a) LANDSAT TM (band 5) image of Rondonia, Amazonia, Brazil (b) Segment edges superposed to the original image.

### 4.2 Radar Image Processing

SPRING includes a set of radar image processing algorithms, which may be used for satellite or airborne radars, which includes speckle noise reduction filters, antenna pattern correction, slant range to ground range correction, and statistical analysis. The combination of region classifiers and radar image processing techniques has proven to be a very effective method for Remote Sensing studies in areas such as the Brazilian Amazonia (Ii and Griffiths, 1996; Yanasse et al., 1997).

### 4.3 Mixture Models

In Remote Sensing images, due to limitations on spatial resolution, the radiances observed at each pixel may result from a combination of signatures from radiances from all the objects contained within the pixel. *Mixture models* attempt to estimate the contribution of each object (indicated as mixture component) to the integrated radiance observed at each pixel.

SPRING includes programs to estimate linear mixture models and to compute derived channels, based on statistics from the component classes of each pixel. These new bands represent the proportion of each component within a pixel. For example, in an area with forest and bare soil, typically three new bands would be generated, one representing the proportion of vegetation, one that of bare soil, and a third indicating how much shadow is present in each pixel. Mixture models have proven to be very useful in Remote Sensing applications, especially in Agriculture and Forest applications (Aguiar, 1991).

### 4.4 Image Restoration

The objective of image restoration techniques is to correct distortions introduced by the sensor during the process of image acquisition. Restoration techniques aim at correcting the blurring effect caused the sensor’s optical and electronic systems. In SPRING-2.0, filters which restore TM and SPOT images are available (Fonseca et al., 1993). The result of the image restoration operation can be observed in Figure 1.


Unrestored 10m resolution image. Right: image after restoration algorithm.

## 5 SYSTEM AVAILABILITY

The SPRING development started in 1991, and after more than 100 man-years of work by INPE and its partners, including extensive field trials and pre-releases, SPRING-2.0 has been available in the Internet at the address `http://www.dpi.inpe.br/spring/` since November, 1996. From our homepage, the user may retrieve executable versions for UNIX platforms (IRIX, Solaris, DEC OSF-1, Linux, AIX and HP-UX), as well as examples and documentation. A version for Windows 95 is scheduled for late 1997.

Universities and institutions interested in obtaining access to the source code may contact Image Processing Division, INPE (e-mail: `spring@dpi.inpe.br)`.

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