SPATIAL ENVIRONMENTAL DATA

Herlin I.
INRIA - BP 105, 78153 Le Chesnay Cedex, France

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Contents

Summary

This paper can be considered as a complement to the one on Non-Spatial Environmental Data. It focuses on the spatial aspects. Dealing with this information first requires the definition of an appropriate geometry either to represent the original data or to define the maps projections.

A number of specific problems and solutions occur for managing these data. Adapted metadata have been defined and are currently under wide investigation to first document this information and to retrieve it through different querying criteria.

Spatial Environmental Databases provide efficient algorithms for processing spatial data, but they can be very complex and very large; in a large research effort these points are investigated, and the state-of-the-art is changing daily.

GIS adds to the databases capabilities for advanced visualisation and computation.

Last, this paper gives some input to the presentation of different available sources for Spatial Environmental Information and for aerial and satellite images. We also give a

short description of the THETIS project which illustrates many of the concepts introduced in this article. See: Non-spatial data, adapted metadata.

1. Introduction

The design of spatial information systems, a set of techniques and methodologies known as geomatics, is becoming a fundamental aspect of the representation and management of geographically and culturally-based human activities. Spatial information systems are computer systems working on data representing spatial information in a wide sense: they make use of data located on, below or above earth.

These systems naturally share many common properties with classical database systems, but the specific nature of spatial data has given rise to more spatial-tied systems called spatial databases. Due to the complex intricacy of spatially-related data, multi-layered representations have become popular, and they form the core of most GIS (Geographic Information Systems).

Spatial information systems tend to be highly complex, because they address different domains for the use of spatial information. Thus, their use by local authorities or administrative institutions is becoming important. They address problems in land information systems, automated mapping, thematic mapping, environmental modelling, resource management, geomarketing etc.

In environmental sciences they give the specialists the remarkable ability to consider new amounts of data sets related to freshly acquired and accurate data, and to allow better integration between different data sets. Moreover, a lot of Internet resources for spatial data or maps are available through the Web.

More generally, IT (Information Technologies) are becoming a cornerstone for the development of environmental sciences: GIS are making intense use of spatial information coming from remote sensing; GPS (Global Positioning Systems) use satellites for location, identification, navigation, and mapping of spatial information. Remote sensing can be used in conjunction with scientific visualisation to enable navigation and interpretation of complex spatial data sets.

In developed countries, the development of spatial environmental data and systems is a recognised issue, and considerable effort is spent on the development, promotion and sharing of geospatial data through all levels of government, private and non-profit sectors, as well as the academic community. The main goal of such initiatives is to promote the use of information technology to achieve considerable advances in topics such as the building of a multi-resolution, three-dimensional representation of earth data sets, global mapping projects, and the definition of international standards for spatial data and metadata. The practical impacts of such projects are efficient natural resource management for providing better tools for efficient decision making by understanding process interactions over coarser geographical regions and large-scale system interactions.

In this article, we try to focus on the important terms and definitions used in the field of spatial information systems, in their relation to environmental sciences. Since it is a vast subject, our goal is to get the reader acquainted with the most fundamental concepts, before he enters the huge ocean of bibliography and internet resources in the field. We will also point the reader's attention on existing and new technological systems, such as the European THETIS project, described in the last section of this paper.

We point out that the reader may use internet search engines to access a huge electronic documentation about spatial systems, and most particularly related to the European community. Since this type of documentation is highly volatile and evolving, it is not included here.

2. Use of Spatial Environmental Information

Over the last few decades, spatial information systems have been increasingly developed and are now considered as basic tools for users ranging from persons navigating through a city street system to policy makers in charge of city planning.

Spatial systems are information systems that manage and manipulate localized data or objects positioned in an arbitrary space, not necessarily geographical. Spatial data often refer to world space data. Locating data with regard to longitude and latitude provides the user with a geographical context, allowing them to make sense of numbers stored in a database. There are various structuring and organising schemes, the most common is based on layers of sets of maps. Each map contains thematic information related to the geographical location. The collection of layers describes a large range of information useful for the user application.

The awareness of the increasing impact of natural and human-induced changes on the global environment has motivated the development of spatial environmental systems. The objective is the understanding of the large set of data acquired by Earth Sciences in order to provide governments and the public with the basis of well founded environmental and resources management policy formulation. An efficient environmental protection policy and/or natural resource management requires identifying the relationships of natural resources, phenomena, hazards and societal data with data derived from earth sciences and satellite images.

For example, in a vegetation-driven application, one can understand spatial environmental data as a layer-based spatial data augmented with layers describing: Land cover, soil, geology, topography, cultural features, water quality, minerals occurrences, weeds, endangered fauna, precipitation, etc. Moreover, due to their changing nature, most of these layers contain dynamical information such as monthly/weekly precipitation.

The purpose of environmental spatial data systems is to assist at least two types of users:

- a policy maker in specific management and planning tasks such as: What would be the environmental impact of the construction of a new power plant, the change of landscape characteristics, etc.

- a scientist in providing a comprehensive data structure for an efficient modeling and understanding of natural processes such as soil and air pollution forecast, crop rendering, coastline erosion, etc.

Therefore, one can understand that combining all these data of various types into a single information system is a challenging task. Indeed, one has to provide tools that allow a user to manipulate and perform tasks on a large set of non-homogeneous data, and since these data are collected by various governmental and scientific agencies, one has to manage a distributed database.

In the following, we will briefly describe the geometries allowing the representation of these various data sets and their classification. See: Spatial data, spatial information system, world space data, dynamical information, distributed database, geometries.

3. Spatial Data Geometry

Environmental spatial data contain a large set of various data such as road and river networks, stream networks, coastlines, elevation maps, land cover, geology, points station, etc. Each of these data is represented in various forms using points, polygons, surfaces, volumes, maps, images, tabular data, etc. The description of these spatial data relies on mathematical tools and methods for characterising the properties of each particular shape. Descriptive geometry is commonly used for this task. It allows the measure of objects properties in space and their relationships, enabling the computation of lengths, distances, angles. The shape description and its properties are usable when represented in a common spatial reference system. It enables the user to make sense of numbers and shapes stored in the databases.

Although there is a multitude of reference systems, a geodetic reference system is used. It is based on a set of physical objects (monuments) which form a basis for establishing the positions of entities on the earth's surface. A global reference system based on the latitude and longitude allows, given two coordinates, the derivation of a unique address for each point on the Earth surface. This spherical representation is usually projected into a planar surface. The purpose is to efficiently represent the spherical surface on a flat sheet while preserving one of the following properties: distance, direction, shape and area. Map projections can be classified into five categories according to geometrical properties such as:

- the form of the surface used for the projection;
- the viewing origin and the standard points and lines used;
- the spatial properties, preserved or distorted;
- the number of points used to transform from a sphere to a flat surface;
- the formulae used for the mapping.

Three common projections are used: projection onto a disk, a cone or a cylinder. The choice of the projection is driven by the application and by the geometric properties that must be preserved. From these considerations one deduces that geometry for spatial data is highly dependent on the way one makes measurements on the surface of the Earth: This is the science of geodesy. The determination of a correct reference geoid is a key concept here. With the advent of satellite imagery, this question has received new insights and particular attention.

Spatial data are organised and represented through different primitives, such as lines, surfaces, solids etc. within Euclidean geometry. It is also possible to make use of different mathematical frameworks, like topology or fractal geometry in order to derive more efficient representations of these data. The selection of a particular representation is made based on the different aspects of the applications:

- two, three or more dimensions;
- planar or non-planar problems;
- continuous or discrete data;
- isotropic or non-isotropic problems;
- time evolution;
- qualitative or quantitative measurements.

See: Reference systems, geodesy, geoid, Euclidean geometry.

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Biographical Sketch

Isabelle HERLIN is Director of Research at INRIA (National Research Institute in Computer Science and Applied Mathematics/ Institut National de Recherche en Informatique et en Automatique, France) and Head of the AIR project. She studied mathematics at Ecole Normale Superieure and received her PhD in applied mathematics (1987) from the University of Paris VI.

Her research interests are:

image processing for satellite data: Apparent motion computation, deformable structures, curves and surfaces matching, temporal tracking, within the mathematical frameworks of variational methods, Markov random fields, and applied physics;

estimation of physical parameters from satellite images: Application to hydrology with estimation of evapotranspiration;

relations between satellite data and environmental models: estimation of input data, estimation of parameters.

Isabelle HERLIN has co-authored more than 50 papers published in international conference proceedings and journals. She is currently on the steering committee of three EC projects (DECAIR, IWRMS, THETIS) including one as coordinator.