Erdvinës informacinës sistemos

Spatial Information Systems

Spatial Context

The conceptual view of spatial information systems emphasizes the comprehensive nature of spatial data use and organization.

Spatial data organization

Contemporary computer- based tools for working with data or phenomena on, above or below the earth's surface

(spatial information systems)

are numerous; they can utilize data of many forms.

Spatial is a term used here to refer to located data, for objects positioned in any space, not just geographical, a term we will use for the world space.

An **information system,** a collective of data and tools for working with those data, contains data in analog form, for example, handwritten notes or photographic slides; or digital form, for example, by computer binary encoding, about the phenomena in the real world.

The physical representations of this information, that is, the data, constitute a model of those phenomena. So the **collection of data**, the **database,** is a physical repository of varied views of the real world representing our knowledge at one point in time.

In the database context the terms **data, information and knowledge** are differentiated. **Information** is derived from the individual data elements in a database - information that is not directly apparent.

In a sense, the information is produced from data by use of our thought processes, intuition or whatever, based on our knowledge. For example, a bicycle can be represented by circles for the two wheels, various lines for the frame, wheel spokes, and so on. The geometric entity of the bicycle is the assembly of the data elements; human **knowledge** is needed to deduce the reality of a bicycle as a means of transportation and the steps necessary for the physical object to function.

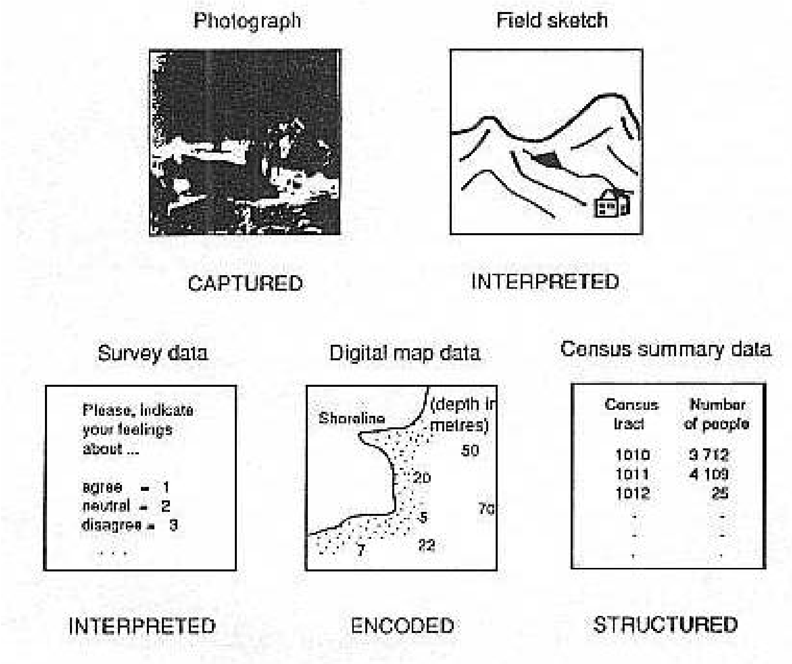
In a less complex case, **knowledge** about world latitude and longitude can allow us to make sense of some numbers in a database.

An x or *y* coordinate is a data element. Extra data are needed to make sense of the magnitude of those numbers. We know that high positive values for x must refer to a place near the North Pole, provided that we have information about the scaling of the axes and how they fit the real world. Having the 'extra data' allows us to produce the information from the data. Interpretation of discrete, apparently unrelated, pieces of data is akin to having 'added value' as we progress from data, to information, to knowledge.

The material in this mélange of “data” has many conceptual origins and forms. The data may be any of the following:

1. **Real**, for example the terrain conditions or buildings.
2. **Captured**, that is, recorded by physical devices like electronic sensors, and film cameras; for example, seismic signals or landscape pictures.
3. **Interpreted**, that is, involving some human intervention as in field sketches of landscapes, a questionnaire, or writing in books.

4. **Encoded**, as in paper maps, digital data for depths of oceans or summary statistics for median income levels.
5. **Structured** or organized in some way, such as tables in census reports or data in geographic information systems.

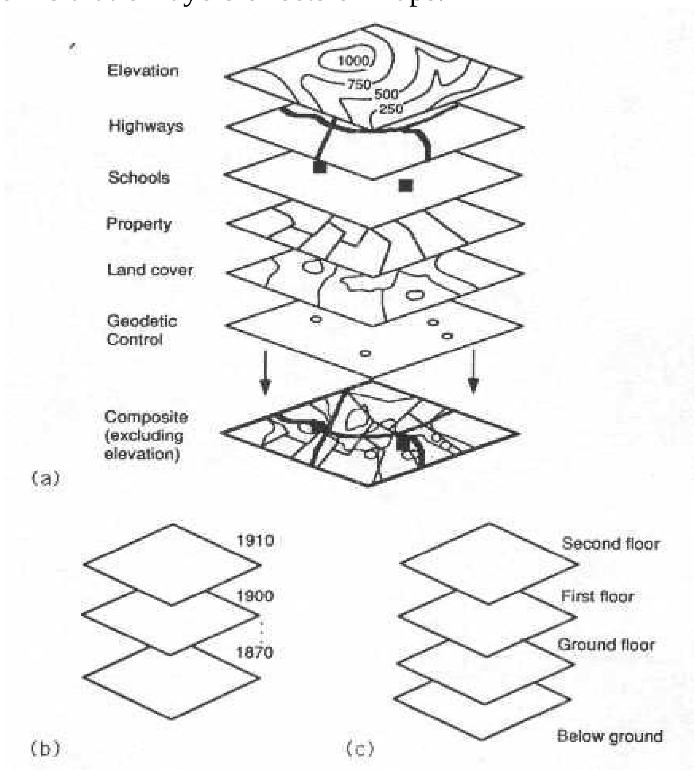


The structuring for this variety of information in an environment of digital computers is the subject of this course.

Various commercial software packages are available to aid this structuring; there are some dominant forms or models for working with spatial data, and there is a growing body of fundamental principles and formalisms to guide us in the process of information and data organization.

By principles we mean a conceptual framework for information organization; and by formalisms we refer to mathematically based representations and organization of spatial data.

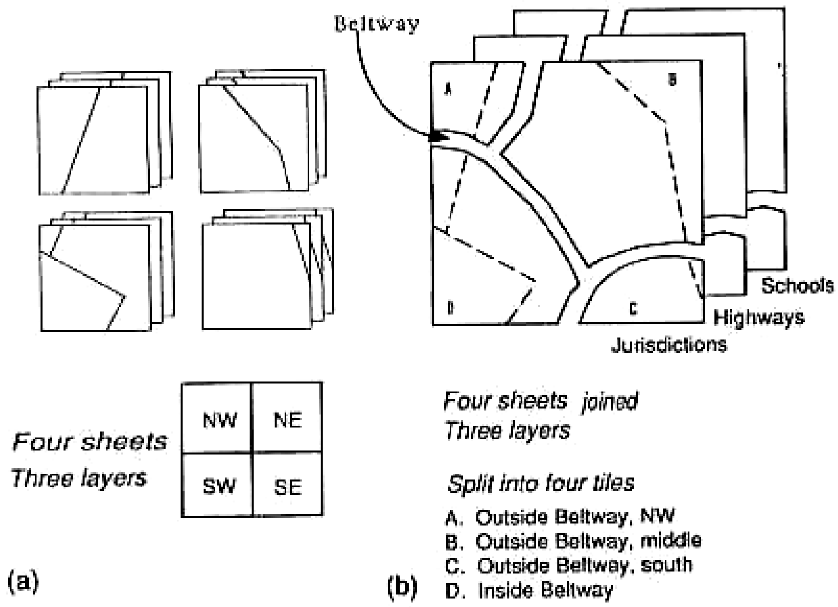
One common organization is that of layers of sets of maps.



Each layer, representing a thematic approach to a particular purpose or set of needs, may contain one or several different kinds of information.

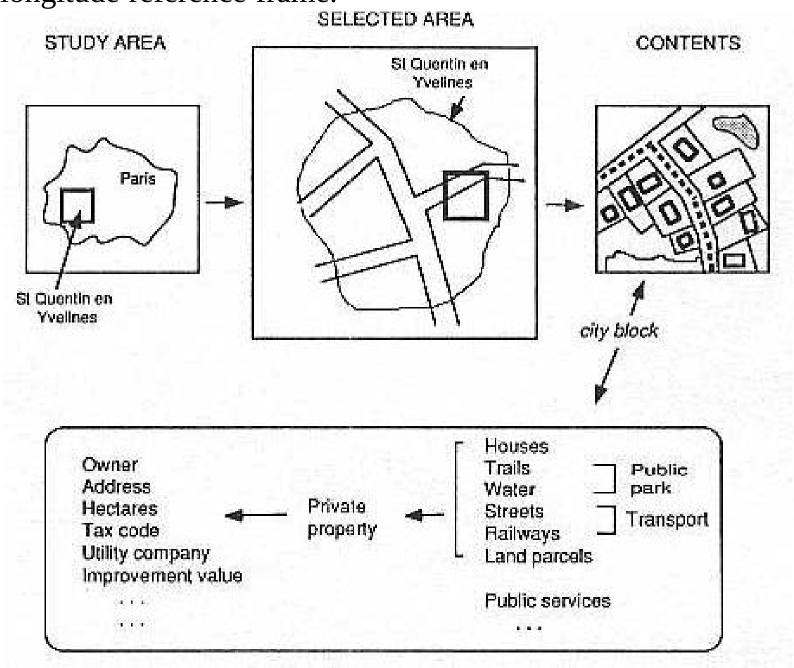
This layered data set approach is associated with photogrammetry, computer assisted design, and map overlay modelling using paper maps. The layer view supposes that we are observing something everywhere. However, the layers may not necessarily be, or only be, themes; they can be different elevations, as for the floorspace use type for different stories of buildings; or they may be different points or intervals of time for a given theme, for example, data from different censuses.

A structuring into themes and pieces of space, perhaps counties or map sheets or special units called tiles, is very common in analog information systems



This organization is also common for automated spatial information systems, reflecting the fact that these commercial products were first developed as digital equivalents to the paper map collections.

Another arrangement works with a single geographic area containing a variety of objects, some, or all, of which may be of interest at any one time. These entities are imagined to be in one layer only, thereby allowing the third space dimension to represent the world vertical variations as well as providing a latitude/longitude reference frame.



This **object orientation** is associated with human cognition and reasoning, but is not so good for dealing with surfaces of real terrain, or gradients of the human condition like spatial variations in personal income.

For all of these general types of organization, there is a more detailed level concerning the **physical representation** of the real world phenomena.

For example, we can imagine tables of numbers for all the roads in a province, or we can think of the roads expressed as a set of lines with associated characteristics represented symbolically (for width, number of lanes, amount of traffic, etc.).

In addition, the physical structuring may not match with a conceptual layering, a concept very useful for user comfort.

Independent of the world of automated mapping, users of spatial data have long worked in a particular mode: the world of the paper map. Such a method of recording and using data for the earth, which we will call the **map model,** is one of the steps along the way to the modern-day digital environment, and is seen in the replication of manual procedures, use of similar terminology, and frame of mind associated with some computer-based spatial data processing.

Heterogeneity of uses

Because the different domains of use of automated spatial information systems have particular needs, it appears at a general level that there are many, perhaps too many, commercial software systems or theoretical models to establish principles or order. The language confusion that can, and does, arise from the use of similar tools in different fields, in part a reflection of the development of the contemporary information systems from different roots over a twenty-five year history, adds to the difficulties in understanding, evaluating, and discussing these automated resources.

Uses of spatial information systems

Today, looking at the worlds of business and government, we see spatial information systems applications, activities and tools for dealing with spatial data with names such as:

- Land information systems
- Automated mapping and facilities management systems
- Computer-aided design
- Thematic mapping software
- Marine cartography
- Remote sensing systems
- Surface modelling
- Environmental modelling
- Resource management
- Transportation planning
- Emergency response
- Geomarketing
- Geotechnics
- Archaeology
- Military exercises

In the large realm of practical uses of spatial information systems, the general purposes include:

- inventory, a data and measurement orientation, as for land resources;
- communication or transportation utilities infrastructures;
- administrative record-keeping, as for property-based taxation.

In these domains, typically large quantities of real world objects are mapped at large scales. Whether or not analytical or querying procedures are used, spatial information systems are often employed as support resources for decision making.

Knowledge of particular requirements is important for appropriate and effective design of the entire system of tools for processing data for earth phenomena.

Data requirements

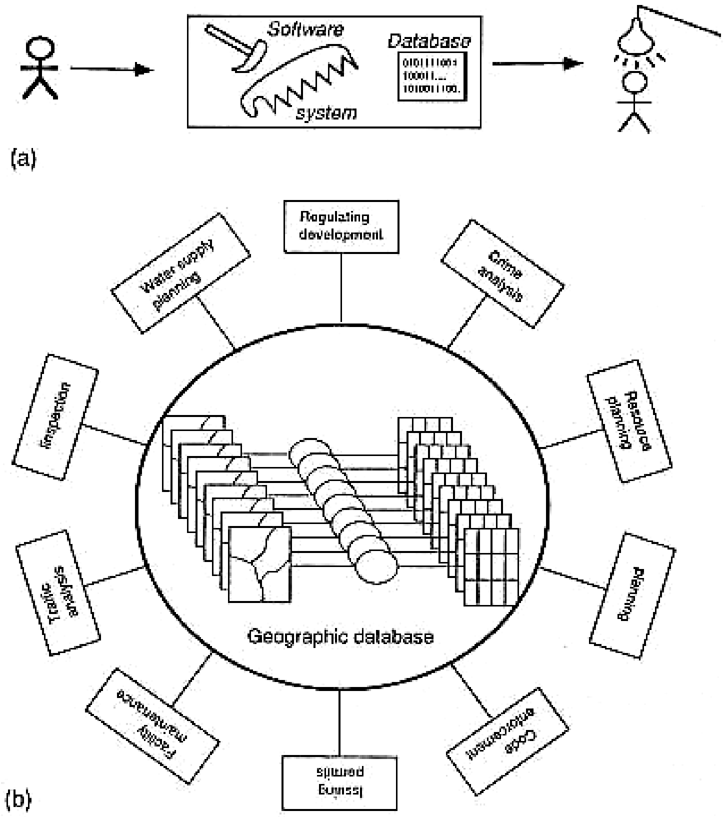
The common elements in the many domains of the use of spatial information systems, are, however, not extensive. Whether we are navigating through city streets or following chemical laden water over a landscape; or whether we are inventorying city telephone poles, or counting forest fires; or designing the layout of EuroDisneyworld near Paris or forecasting the weather for the Commonwealth Games in Auckland, New Zealand; or planning the extension of a sewer system underneath the streets of Moscow, Russia, we deal in a general sense with just the following few features like:

1. Phenomena that vary in character from place to place.
2. Natural features with unclear boundaries or no boundaries at all.
3. Person-made phenomena with clear limits.
4. Phenomena located in space, either geographic (earth) or arbitrary.
5. Entities that are related or unrelated to each other by location.

In other words, we deal with properties of spatial entities positioned in a spatial reference system.

SOME COMPONENTS OF SPATIAL INFORMATION SYSTEMS

An automated spatial information system is a toolbox for representing views of the real world via data about locations. Spatial information systems are a technology for processing spatial data. The tools, which may be activated by pushing a button or typing a command, represent processing functions or operations for example, drawing a map, or measuring the distance from Paris to Madrid. The tools work on some or all of the information stored in some systematic way in a database. The information system requires data, software, hardware, 'brainware' and other resources, and exists within some institutional setting as a **resource** to solve problems.



The toolbox view

The support for decision making, practical or academic, may consist of virtually instantaneous answers to questions, a **query** type of system.

For example, the best route for crossing a city is displayed in map form for the vehicle navigator, or the urban geographer can quickly find which cities in Europe are less than 100 kilometres from any national frontier.

Or the information system may be oriented to producing information, perhaps in the form of maps or tables, for subsequent study.

Products may be detailed maps for public briefing purposes in a re-zoning case, or may be the complete set of possible routes through a city street system.

Whatever the medium, the output is designed for further study, is generally extensive and is not designed for immediate consumption.

In contrast, the query mode provides quick-responses to highly focused questions usually in the form of small amounts of information. In providing these capabilities to the user, the spatial information systems must, at a general level of detail, fulfil the following:

1. Provide tools for the creation of digital representations of the spatial phenomena, that is, data acquisition and encoding.
2. Handle and secure these encodings efficiently, by providing tools for editing, updating, managing and storing; for reorganization or conversion of data from one form to another, and for verifying and validating those data.
3. Foster the easy development of additional insight into theoretical or applied problems, by providing tools for information browsing, querying, summarizing and the like: that is to say, facilities for analysis, simulation and synthesis.
4. Assist the task of spatial reasoning, by providing for efficient retrieval of data for complex queries.
5. Create people compatible output in varied forms of printed table, plotted map, picture, scientific graph and the like.

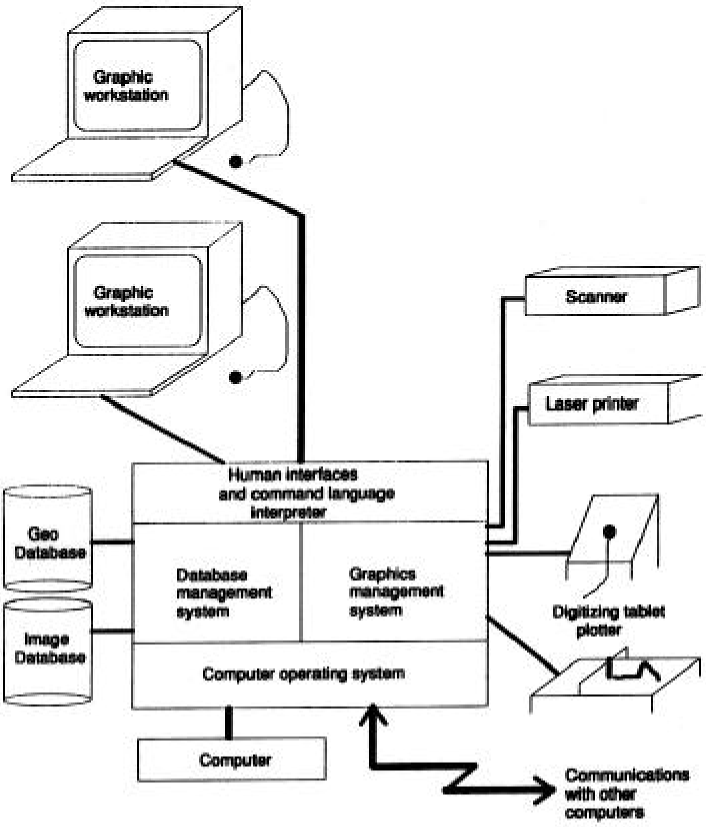
In a sense, the spatial information system lies within a larger framework of information requirements of the human world. Then the information subsystem itself has a physical component (the hardware and data encodings), the documentation component describing the characteristics of the spatial information system, and the guidance component (the person who looks after the database and tools, and solves malfunctions).

Consequently, beyond a general level of the domain of the use of spatial information systems, we can begin to appreciate differences in terms of

General purposes
Themes of information
Types of data
Particular tools
Specific processing requirements
Specific forms of data organization

The physical components

A spatial information system is a software product which has several components and makes connections with other devices in its environment.



In structure it includes a database management system (DBMS) for storing and managing data, linked with a graphics management system for cartographic or other visual displays. These two software subsystems are connected in one direction to the computer operating system, and in the other direction, through graphic workstations, to users by means of an interface and a command language interpreter.

The main devices used in a spatial information system are disks for storing various data (alphanumerical, graphic and image), digitizing tablets and scanners to enter graphic data, and plotters and printers to present the results. Similarly, as for all computer systems, it is valuable to have the spatial information system computer linked to a communication network allowing the exchange of data with other people or companies providing or working with geographic or other spatial data.

THE ROLE OF AUTOMATION: GEOMATICS

"Seeing relationships based on geography" is a selling point today for many practically oriented fields. Perhaps 80 per cent of decisions by state and local governments involve a spatial component either directly or by implication. Geographers are used to thinking spatially, and geography has the same common intellectual root as geometry. Architects, either building or landscape, work with spaces. So our search for organization of material about spatial information systems has to look to many disciplines and fields of study. These are:

1. Disciplines that have developed concepts for dealing with space: cognitive science, geography, linguistics, psychology.
2. Fields that develop practical tools and instruments for obtaining or working with spatial data: cartography, geodetic science, photogrammetry, remote sensing, surveying engineering.
3. Disciplines that provide formalisms and theories fundamental to our working with space and automation: computer science, geometry, informatics, artificial intelligence, semiology, statistics.
4. Fields making substantial use of automated spatial information systems: archaeology, civil engineering, forestry, geotechnics, landscape architecture, urban and regional planning.
5. Fields that provide guidance about information: law, economics.

The strength and intellectual interest of the spatial information systems subject derives from the cross-fertilization among these many fields. While some writers use the term geographic information systems to refer to the composite field of study, we prefer the term **geomatics** as an umbrella covering all the fields listed above that are today important for understanding and further developing spatial information systems.

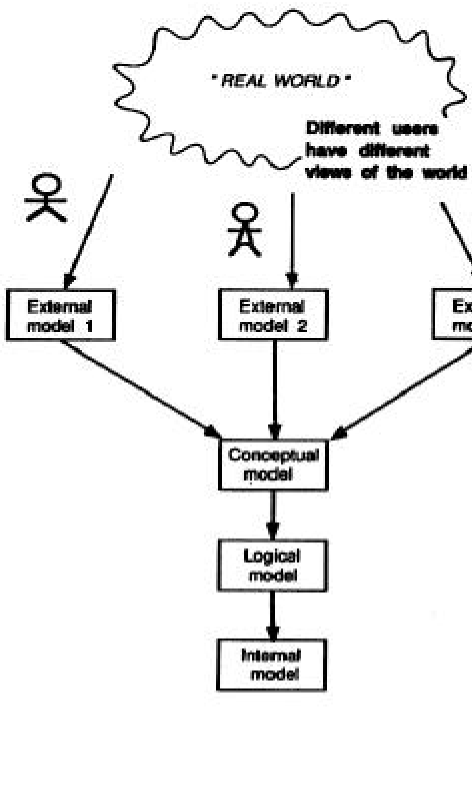
Ideas and tools from many fields are, then, necessary for a full understanding of spatial information systems. As user requirements and expectations increase for such resources and toolboxes, so there are intellectual pressures on the theoreticians and practitioners of geomatics to cooperate in interdisciplinary research studies and development projects to further improve our automation tools.

For example, in the USA the National Science Foundation is providing about $6 million over a five year period for a group of scholars to undertake a thirteen-item research plan. This plan covers much theoretical research into topics like spatial statistics, methods of spatial analysis, database structures, visualization of spatial data and results of empirical research involving spatial entities, the use and value of geographic information in decision making, modelling time alongside space, the integration of remotely sensed data into geographic information systems, and understanding human spatial cognition. A nationally funded research programme is also active in Regional Research Laboratories in several British universities, in a major university in The Netherlands, and elsewhere in the world.

Notwithstanding the impressive and comprehensive statement of research tasks indicating, according to many scholars, that we know little about spatial information systems, we have attempted to organize much of what we do know in a systematic fashion. Our focus is on organizing principles and instruments that help us to understand, evaluate and design spatial information systems - in a sense, a course in appreciation based on many examples, much like an understanding of fine art comes about by looking at and studying many pictures.

We may accept automation as the way of the last decade of the twentieth century, but we must also have a view of non-automated spatial information systems, for most of the information about and guidance of the world's physical system are not yet within a computerized environment. While the concepts of data structuring, concepts of spatial relationships, and matching tools of drawing and tabulating existing in the non-automated world have been taken to the automated world, it has not been without cost. So we presume, on the one hand, that the spatial information system in a computerized environment allows some problems to be handled more efficiently and cost effectively. On the other hand, we expect to be able to undertake problems otherwise considered insoluble. Automation allows faster creation and use of large quantities of information, speeds up mathematical or logical operations on data, and makes possible tasks that are otherwise unmanageable.

The **spatial information system,** then, is a computerized environment whereby utility programs performing specific functions are used in an integrated environment, in which the user is shielded from the details of computer processing, to achieve some goal of research, education or decision making. The inherent form of spatial data representation and organization must be designed to support effectively and efficiently the kinds of query and analysis required by many users. The performance of computer systems is a reflection of hardware technology and software engineering, but also reflects the data structures and the quality of algorithms. We approach the question of design of spatial information systems at the conceptual level:



Using the terminology from the field of informatics, the real world is seen from an external view, representing the needs, objectives and process of extraction on the part of different people or organizations. Each such subset of the real world can, referring to the information system toolbox, be thought of as an application.

Conceptual modelling covers the synthesis of the external models. It is here that we can think of common ground among users, in part the universe of discourse, in part the universe of modelled entities. Using tools and formalisms, the phenomena of interest are identified, their pertinent characteristics described, and how objects relate to each other is mapped out as well as possible. Different views are integrated via a common language and structure.

The **logical modelling** stage translates the conceptual organization into something more practical, perhaps simply thought of as putting numerical values into tables of data, but avoiding the details of storage of data on physical media. It is at this level that phenomena are organized into a database as tables of data records and connections to other tables.

The **internal modelling**, which we do not address, treats the organization of data on hardware storage media.

As automation for spatial data handling has proceeded from making graphs and then maps, to automated mapping and thematic cartography, to tools for inventory and management, and then to database resources for decision making or education, so it has become more important to think about the value of the information in the database. The contents, certainly reasonably viewed as a commodity, are presumably valuable for one or more purposes, yet such data alone are not enough. Users provide the added value by interpretation and analysis, and by understanding the nature and quality of the data. It is important to focus on the message, the contents of the envelope, not the messenger, the postal system. Consequently, our discussion of data structuring in an automated system is put in the context of the semantics of the data.

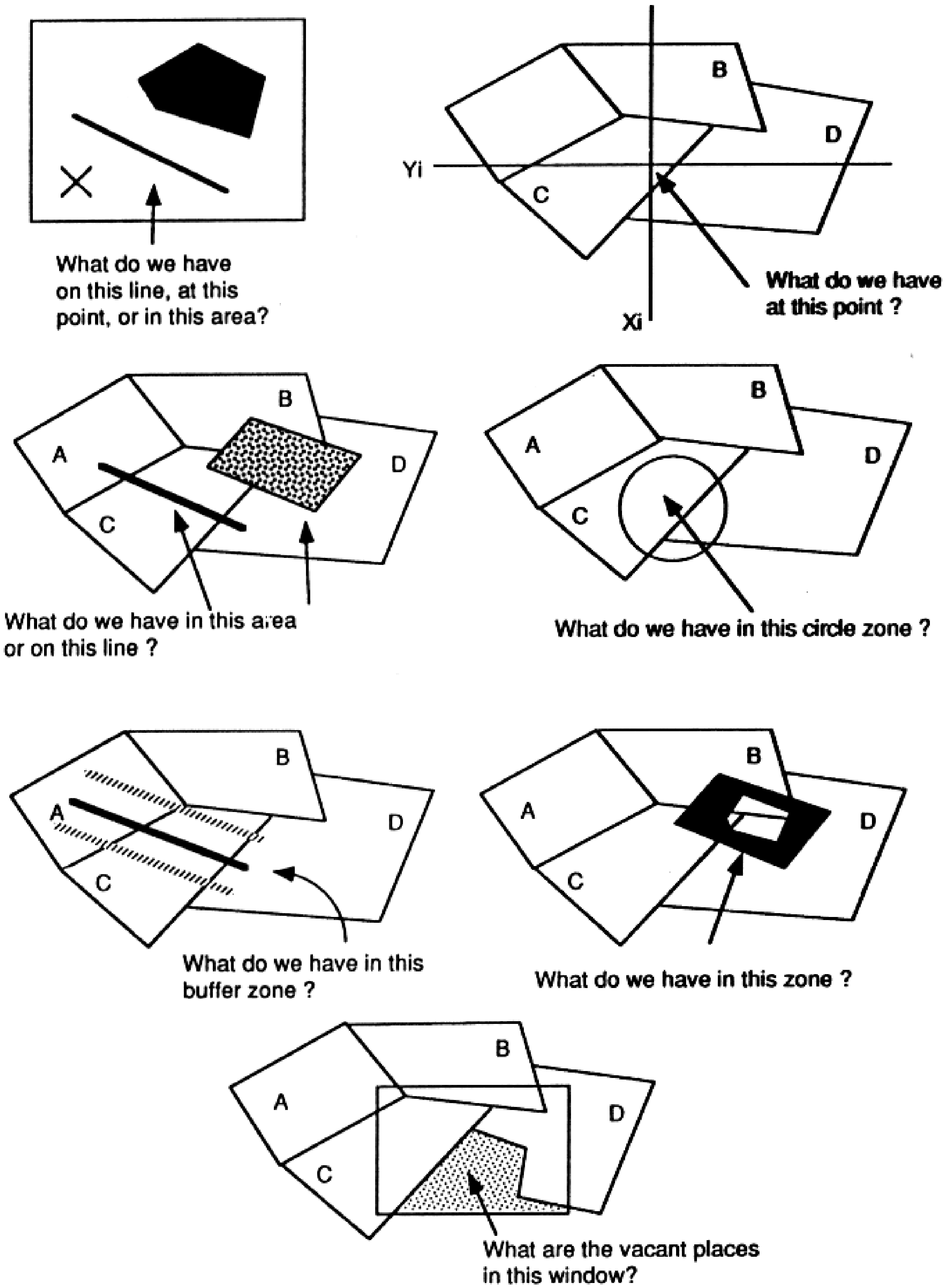
Automated spatial information systems, then, are many things to many people. By way of summary, they are:

A data depository
A toolbox
A resource
A technology
Frames of mind, one or several

As a set of software processing routines in a hardware setting they are a new kind of toolbox for practical problem solving. As a new resource compared with paper based map making, they represent a new technology; and, through their emphasis on spatial data, they stand, for many people, for a different approach to thinking about problems and knowledge.

Computers provide compact forms of data storage, fast retrieval and mathematical equation solving; can store vast quantities of information, but especially allow linkages to be made among separate and apparently unrelated pieces of data. But computers are not enough. The users of information systems must have a good sense of human error and be capable of making wise judgements. The path from the real world to people's views to digital encoding must be trodden with care; otherwise we will not be able to make the return journey, from data to information to knowledge.

Needs: purposes and types of spatial problem


What do we have
on this line, at this
point, or in this area?
B
D
Yi
C
Xi
What do we have
at this point ?
A
B
C
D
What do we have in this area
or on this line ?
A
B
C
D
What do we have in this circle zone ?
A
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What do we have in this
buffer zone ?
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What do we have in this zone ?
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B
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What are the vacant places
in this window?