GIS in practice

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Abstract:

From the second half of the twentieth century onwards, with the developments in computer technology, also a technology was developed to capture, store and analyse spatial data; the systems that became available on the market were called Geographic Information Systems (GIS). This technology, in many aspects, replaced the tedious map making process for all kinds of applications in the field of spatial activities.
It is impossible to present all aspects of GIS in a short overview and so only the following subjects will be part of this chapter. First different definitions of a GIS will be given; it turns out that most of them only deal with the technological aspects: therefor attention will be given to the other aspects as well. Then some application fields of GIS will be introduced In fact this could be an infinity list but only the most striking application fields are considered. After a historical overview of GIS development, the common GIS functionality will be introduced from both the scientific and practical point of view. The design and implementation of GIS requires the data definition, following the rules as are applied in ICT and the use of the universe of discourse is introduced for this definition. Data is gathered in sets and the use of set theory is applicable for GIS databases. Geometry is a very striking aspect in GIS making them different from other ICT databases. Geometry in GIS consists of location, shape and topology. The data collection in a GIS is cumbersome and expensive, therefor the GIS system architecture, interoperability for data sharing, database integration and the use of quality in GIS becomes an important issue in GIS applications.

Introduction

The growing need for efficient use of the earth's resources of land, air, water and raw materials as well as for the many different activities in a complex social and economic society requires a better insight in the spatial and temporal patterns of society's resources and activities.
In the last 300 years maps where applied for these applications to assist an interpretation with spatial characteristics. However, map making resulted in a common end product: the same printed map on a flat sheet of paper to be used for many different types of problems. Cartographers, geographers, landsurveyors and later on also photogrammetrists were traditionally heavily involved in this process. They were seen as the experts of what should be mapped for the different purposes that the maps were assumed to serve.

The routine collection of data still may be there; however now new equipment and methods are applied. Striking is the new series of products resulting in digital files containing data representing real world phenomena. In the digital mapping era the data producers enhance the collected data by structuring them into databases for easy later access, introducing topology and other relationships between database objects and also including enhanced attribute information for analysis purposes. This determines the richness of the data for so many different applications but - unlike in the situation with printed paper maps - now, the use of the data is completely out of the control of the original data collectors, who collected the data for specific purposes only.
Many of these databases are updated by several organisations, kept at different places but made available through digital transfer networks. It allows new data users to add new attributes to existing database objects and add new objects or relationships for their specific purposes. They also often

combine different datasets with different resolutions and quality from different sources, solely to satisfy their needs. And so any dataset may be the product of a number of data producers, and/or of different sources.

Apart from the need for topographic data, also the need for different themes about the earth surface grew for resource exploitation and land management. Some contemporary applications, using GIS, can be found in [Burrough, 1988]:

- *archaeology* for site description and scenario evaluation;
- *agriculture* for agriculture production, landscape design, land development, land reclamation and hydrology;
- *emergency services* optimising of routing for police, fire brigade and ambulances and understanding spatial aspects of crime;
- *environment* to monitor, model and manage land degradation, landslides, desertification, land, water and air quality and quantity and weather and climate modelling;
- *forestry* to manage wood production, transport and replanting;
- *geography* for social studies and demographic and physical changes on the earth;
- *health and epidemiology* for the location of diseases in relation to spatial aspects;
- *marketing, economics and tourism* for site location of target groups and to design the location and mange facilities of attraction;
- *physical planning* for regional and local planning and the development of plans, and its costing, maintenance and management;
- *real estate and land property registration* concerned with legal aspects of the cadastral property and property value and insurance;
- *utilities* for planning and managing water, gas, electricity and telephone distribution and other cables and pipeline services, etc.;

Nowadays data is made available by topographic mapping organisations, land registration and cadastres, hydrographic and oceanographic mapping organisations, military organisations, private companies making and distributing remote sensing and satellite images, geological and soil survey departments, etc.

GIS definitions

There have been many attempts to define GIS (Fig. 1). They all have in common that a GIS contains spatially referenced data about phenomena from the real world in relation to the earth surface. Many of the GIS definitions also indicate the technological aspect of capturing, storing, analysing and representing the analysed results of the data.
However, from application point of view in most fields, software is developed separate form the GIS to analyse the theme of concern and the technology in the GIS system only plays a minor role in these application areas. E.g. the network analysis for a route planning and traffic control system can be done by home made software using the topology of the network as long as the database contains the thematic information of the road properties and the exact location of roads and nodes becomes of minor importance. The topographic information may help for the location of the roads in the terrain in case of traffic problems. So the use of a GIS involves the connection of the GIS to the application software and its design.
Many applications dealing with GIS are subjected to the regulations and laws in the application field. The design of a traffic system, as in the previous example is subjected to municipal permission following the rules on road use and road planning. Another example is the property registration for real estate that is legally described by a cadastral law. Landowners and the cadastral employees are

"*A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world*" (Burrough 1986)

"*A system for capturing storing, checking, manipulating, analysing and displaying data, spatially referenced to the Earth*" (DOE 1987)

"*An information technology which stores, analysis and displays both spatial and non-spatial data*" (Parker 1988)

"*A database system in which most of the data are spatially indexed, and upon which a set of procedures operate in order to answer queries about spatial entities in the database*" (Smith et all. 1987)

"*Any manual or computer based set of procedures used to store and manipulate geographically referenced data*" (Aronoff 1989)

"A*n automated set of functions that provide professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data*" (Ozemoy, Smith and Sicherman 1981)

"*An institutional entity, reflecting an organisational structure that integrated technology with a database, expertise and continuing financial support over time*" (Carter 1989)

"*A decision support system involving the integration of spatially referenced data in a problem solving environment*" (Cowen 1988)

Fig. 1. Definitions of GIS [Burrough 1998]

bound to apply the system according to these regulations. Designing systems for cadastral registration should also include these regulations and allow only the legal situation.
In order to apply GIS in the areas society is asking for, one should realise that GIS is a complex technique, requiring many skills. And so, the education should cover all aspects that may become of interest for people working with it, including the technological, legal personnel and managerial views on the use of GIS in relation with the application models.
Often, the technological aspects of GIS are touched only slightly while legal, personnel and managerial topics are neglected at all. Since the amount of data for GIS and the availability is growing drastically through the Internet, the design and technological aspects GIS, network connections as well as the use of quality of GIS data in combining different sources of data will play a more important role. Therefor, in this presentation the accent will be on the technological aspects of GIS.

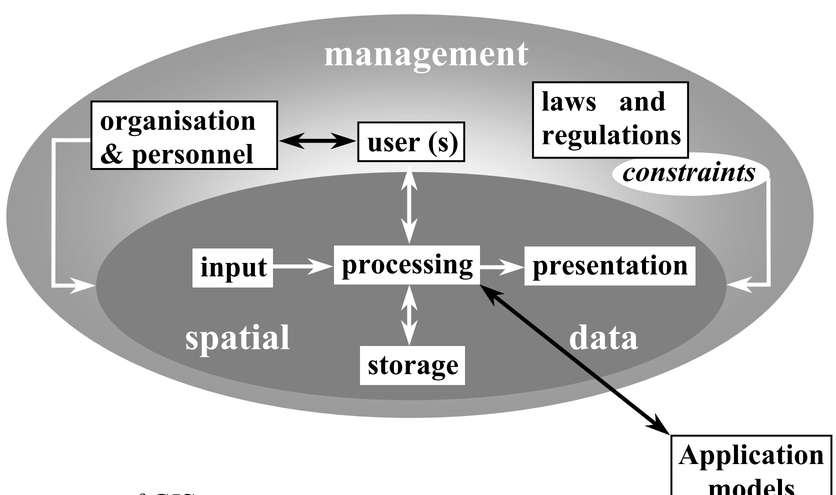


Fig 2. Different aspects of GIS.

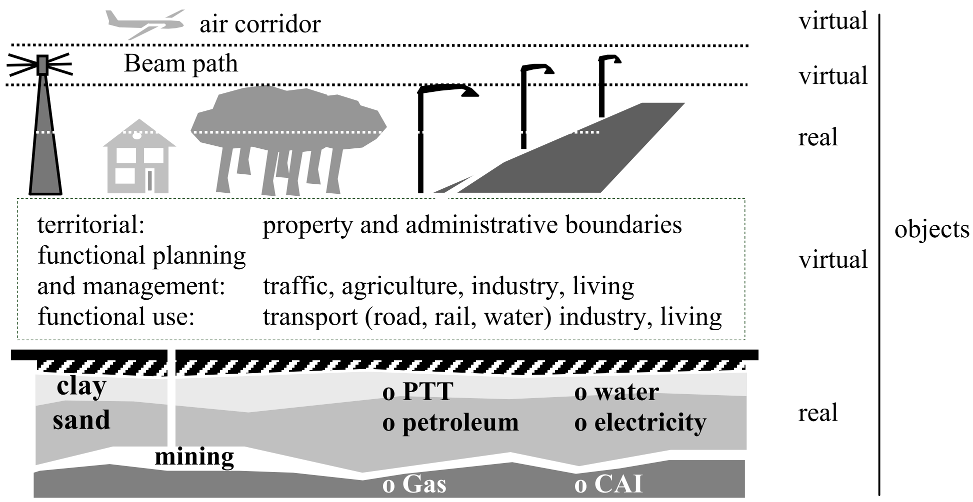


Fig.3. Types of GIS objects: to be subdivided into real and virtual objects.

Why GIS ?

Different from the period that analogue maps were used for spatial analysis, GIS offers the option to attribute each instance operations, using both the spatial and non-spatial attributes of an object in the terrain with the appropriate characteristics. This is opposite to packages as SSPS, where only statistical operations can be applied to non-locational aspects, as well as to CAD system that only allow for spatial constructions and operations as circumference or area determination. Specific operation for GIS can be based upon:

- Location: *what is in the surroundings of …?* The answer may be an place. (E.g. Toruń, or a co-ordinate);
- Condition: *where is …?* The answer can be a set of locations that fulfil all conditions. (E.g. the location of all university buildings in Toruń);
- Trend: *What is changed since …?* Introducing the aspect time; so answers shows differences in time (e.g. all buildings that were established in Toruń between 1990 and 2000);
- Route: *What is the best way to …?* Based on the existing network the answer may show the shortest, quickest or nicest route between two locations (e.g. from Delft (Nl) to Toruń (Pl) using either private or public transport);
- Pattern: *Compare this area with … ?* These problems are more complex due to the combination of data in different situations. (e.g. map student hostels in relation to pizzeria's in Toruń showing the best routes for delivery of pizzas);
- Model: *What if …?* Used in prediction and planning.

Historical background

The development of GIS is strongly influenced by some smaller disciplines as forestry, cadastres, utilities, regional planning and specifically defence. Also national statistical organisations promoted strongly GIS as the US Bureau of Census (USBoC) and CGIS of the Canadian Ministry of Agriculture. To perform census research in 1980 the USBoC designed the GBF/DIME, while the Canadian GIS was set up for the inventory the natural resources within the country in the end of the sixties (often seen as the first GIS in the world).

The academic society contributed strongly to the development and use of GIS. Well-known institutes are the Harvard Laboratory for Computer Graphics and NCGIA from which many researchers have contributed to GIS hard- and software companies as Intergraph and ESRI.
Utility companies used CAD systems for facility management while national cadastres and municipalities based their GIS applications on large scale topographic and property maps.

Nowadays, the traditional differences in the applications based large scale topographic information management (using CAD for LIS and AM) and analysis based on medium and small scale topographic and thematic data disappear and GIS is applied for all kinds of spatial-temporal problems.

GIS functionality

The necessary functionality in a GIS has been a topic for debate over many years and in many disciplines. One may view this from an academic point of view [Rhind and Green, 1988], from practical point of view or from design point of view. Because of the large diversity of GIS applications their list is incomplete and many more functions can be mentioned [Dangermond 1990]. A comparison of different systems learns that over 600 different functions are required. The functional characteristics of GIS can be categorised according to the technology as indicated in fig. 2:

- *Data input, coding*.
  Collection of data from the real world using digitising, landsurveying and photogrammetric techniques as well as data validation quality control and error detection;
- *Data manipulation*.
  Conversion from raster to vector geometry and reverse are required, as well as conversions into different geodetic systems and map projections, Also continuous conversion of data into different scales (map generalisation and aggregation, both conceptually and graphically), presentation improvements of images or line defragmentation techniques are required;
- *Data query and analysis*.
  Selected query based on semantic or spatial criteria is related to the structuring of the data within the database and its geometric representation. Standard query language as SQL should always be applied.
  Spatial analyses as polygon overlay, routing, surface and network analysis are often applied techniques in GIS. Special caution is required regarding to order of such operations in order to obtain the optimal processing time.

Abbreviation	Description
AM	Automated Mapping
CAD	Computer Aided Design
DTP / DM	Desk Top Publishing / Desk Mapping
ESRI	Environmental Systems Research Institute
FM	Facility Management
GBF/DIME	Geographic Base Files/ Dual Independent Mapping Encoding
GIS	Geographic Information System
ICT	Information and Communication Technology
IP	Information Processing
LIS	Land Information System
NCGIA	National Centre for Geographic Information in America
SIS	Spatial Information System

Fig.4. Used abbreviations in GIS.

Statistical analyses may be used from external packages as SPSS for frequency and multivariable analysis or linear regression. Geometric calculations as length, area, volume and circumference are standard in all GIS's;

- *Data representation*.
  Graphical presentation of data in maps and charts on paper or on screen is a standard facility in a GIS but also additional to reports or being an integral part of a reports.
- *Data management*.
  Specific attention should be given to data storage and structuring. Both the conceptual structure including topology as well as the physical access techniques as tiling and indexing are needed for large databases in order to comfort quick and easy data retrieval from the database.
  Integrated database management for large volume of data is required, while distributed networking become more and more used since the combination of data from databases at different locations with different type of attributes is necessary.

Universe of Discourse

In the experience of the old traditional data collectors, the real world phenomena are abstracted and used for map representation. In the Geo-ICT field the same concepts are used, assuming that the real world is composed as a set of separable real world phenomena. For database design, objects are selected from the real world, abstracted and classified into object-types that may have mutual relationship-types. Each of them has specific characteristics called attributes. By convention any occurrence of an object-type has at least two attributes, being its unique identifier and class-name but may have more attributes (multi-valued attributes). In analogy, any relationship-type has at least four attributes: the identifier, the name of the relationship and at least two identifiers of occurrences of mutual related object-type occurrences. Also here more attributes may exists.

The important difference between general IT and the Geo-ICT applications are the objects themselves. Geo-ICT is concerned with the digital representation of real world objects, i.e. phenomena that exist in the real world and are physical and concrete such as houses, forests, rivers, canals, etc., as well as abstract (virtual) objects as administrative boundaries, etc. This is in contrary to general-ICT entities that are representations of - usually - abstract real world objects such as names of persons, bank accounts, addresses, etc.

As many philosophers do not accept the existence of an objective reality (i.e. a reality which is independent of the human interpretation), in GIS there is a general acceptance of an objective reality. Such a reality consists of observable objects with observable characteristics and relations and which is interpreted in the same way for all later applications.
In creating digital geographic data, it is attempted to model and describe the real world phenomena by using ICT concepts for use in computer analysis and graphic display. Any description of the reality is always an abstraction, always partial and always just one of the many possible ‘interpretations’. This is often called model of the real world and is not an exact duplication: some things are approximated, others are simplified, and some are ignored. There is no such dataset as perfect, complete and correct or it would be the reality itself. To insure that the data in a dataset is not misused, the assumptions and limitations affecting the dataset must be fully documented.

Phenomena in the reality are defined into an abstract form by position, theme and time (in order to make these objects intelligible and representable in a database). This abstract view is called the *universe of discourse*[1] (UoD), i.e. from the potentially infinite characteristics of objects in the real world only those that are required for a certain (set of) application(s) are selected and defined for the UoD. All human beings observe the reality with their senses and create a model of the reality in mind. In general this model is not objective: different persons have different concepts of the reality resulting in subjective models. To determine a generic concept for a spatial information system these differences will be generalised by objective rules. This process, describing the selection and abstraction of objects from the real world into an ideal concept through predefined rules, reflects the expressed and intended use of the dataset (see figure 5).

Aiming at such a dataset, it is necessary to precisely define the process allowing the dataset to be derived from the real world. This process is decomposed in two steps:

- *conceptualising*, containing both the selection of what should be considered in the real world and the abstraction of the selected objects, resulting in the contents specification;
- *mensuration*, specifying the measuring methods, the measurement requirements and the capturing and storing of data itself.

To fill the conceptual gaps between the real world and the universe of discourse and between the universe of discourse and the dataset, two types of quality indicators are to be defined:

- for the specifications and abstraction of real world objects to defining of the universe of discourse the quality of this part of the process is called *'semantic quality'*;
- the UoD forms the basis for specification, against which the quantitative contents of datasets is tested. The difference between the contents of the dataset according to the definitions in the UoD and the actual contents in the dataset indicate the quality of the data in the dataset called *'data quality'*.

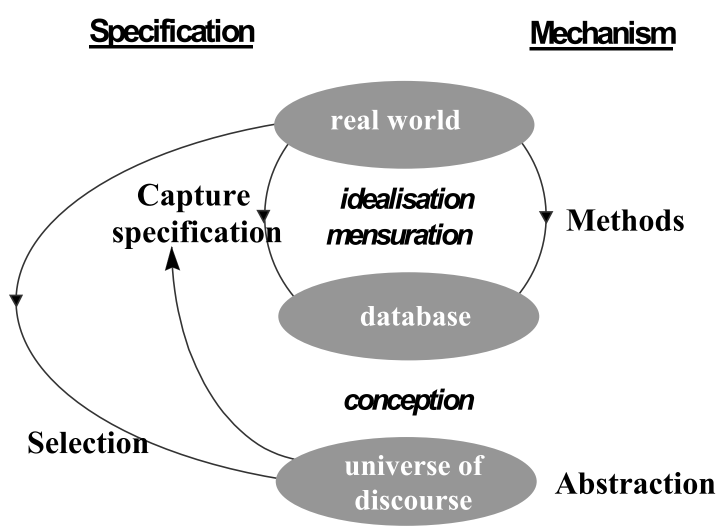


Figure 5. The use of the universe of discourse.

[1] in French: 'terrain nominale', or in American 'abstract view of the universe'. Unfortunately these terms do not indicate the selection process, while that is an integral and important part of the definition of the universe of discourse.

So, the result of the UoD can be seen as the definition of the intended dataset in an ideal situation. Such a dataset does not exist: it is the equivalent to the ‘true value’ in observation theory and will always be unknown. The UoD should be seen as the abstract definition for the dataset. Defining the UoD by the specification of the selection and the abstraction for capturing and evaluating a dataset, the same principles can be applied as can be done in observations theory. This allows to apply the same statistics for preparing a quality report of the dataset, referring to the difference between the actual dataset and the UoD (see fig. 5). It means that only a dataset estimate can be obtained by gathering data from the real world or the mean of several gatherings of the same geographical extend according to the same specifications.
The whole process to create a digital representation in a database of the defined real world objects can follow the lines as indicated above. However, during the measurement also an abstraction takes place: to make the semantics of the real world phenomena digitally representable, i.e.: in the reality points are chosen to represent the geometric characteristics as well as a classification is given to real world phenomena. In other words, during capturing, the abstraction of the real world also takes place in order to represent the object’s characteristics digitally (or graphically in earlier times). This abstraction (also called *idealisation* of the reality) is different from the abstraction necessary to define objects in the UoD. For example if the middle of a stream is to be measured, one may stake out the middle by poles. This can be done with a geometric precision of about one metre. The measurements of the pole may be with a geometric precision of 5 cm. or better. Still the final precision of the recorded middle of the stream is about one metre. So, one has to separate the idealisation precision and the measurement precision. The aim for the idealisation precision may be set in the UoD for a certain type of object class; the aim for the measurement precision should be set in the measurement documentation by defining the methods and its specification.

Some GIS-experts state that it will be impossible to create a complete data definition for their application. E.G. soil surveyors learn novices in the terrain to distinguish between the different classes, since an abstract definition will hardly encompass all different situations that occur in the terrain. However, in this situation there still is a UoD: not written on paper or in a computer readable conceptual schema but in the minds of the soil surveyors.
When creating a database, it will be always required to describe to the data capturers what data should be collected, before they go into the field, in order to ensure that all data capturers apply the same or similar rules in the field. It will be clear that experience will improve the data definition and should lead to an improvement of the UoD during the capturing phase. This can be seen as a mutual influence between the definition of the UoD and the collection of data for database filling.

The data representing the objects defined in the UoD are of two different types. Depending on the nature of the objects they may continuously cover the whole geographical extend that is of concern for the intended application. This is called a *field-based GIS*. Other object definitions may result in an incomplete coverage of the extent of interest, leaving gaps in between these objects. These are called-*object based GIS*. Both types of GIS are applied very often: cadastral or other administrative systems and photographic images are examples of field-based systems, while topographic mapping is an example of an object-based system.

Elements of the Universe of Discourse

The UoD is defined by the specifications of the dataset, containing at least the following information:

1. *object class definition*, e.g. a building is ......;
2. *conceptual schema for the object classes*, e.g. a building is subdivided in public or private buildings or buildings for living, public or commercial activities;
3. *reference system and units* for quantitative attributes and geometry, e.g. height are given in metres;

4. *selection criteria*, e.g. only buildings higher than 3 metres shall be selected;
5. *accessibility*, e.g. due to military classification or technical obstruction data cannot be obtained. Accessibility may influence the quality parameters such as completeness, but it is not a quality parameter itself;
6. *geometric representation*, e.g. a building is represented by a rectangle but also whether vector geometry or raster geometry is used;
7. *constraint rules* as topological rules, constraint on attributes, etc.;
8. *aim for quality*, e.g. completeness is expected to be ......;
9. *resolution* i.e. how precise one may represent an entity. E.g. co-ordinates will be rounded to the nearest decametre, or the size of the pixel is 20 metres;
10. *time of reference*, e.g. the reference date is the date of the aerial photograph;
   update policy will define the kind of updates that will be performed on the dataset;
12. the type of information included in *lineage* should be stated in the universe of discourse.

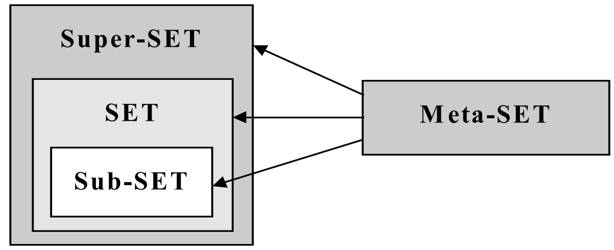


Fig. 6. The concept of sets in GIS.

Datasets

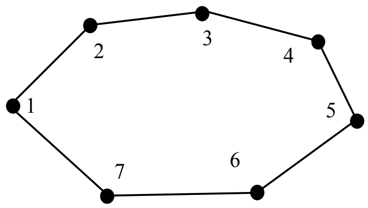
As in ICT, GIS data are stored in datasets. However, datasets are not only used for storing data but also for organising the data (files). For metadata- or quality descriptions, separate sets of data are used, called metadata sets. Several datasets can be combined into larger sets, leading to the aggregation of the metadata from the smaller sets into a new metadata set. This leads to the mathematical approach of using set theory where sets can be distinguished as sub-sets, sets and super-sets, with data about these sets are in metasets.
Data in metasets do not act as part of datasets but merely describe the data in the dataset and form datasets with its own hierarchy. The datasets' specifications are supposed to describe all the elements in the dataset. Homogeneity is required for the whole dataset; i.e. the specification of the universe of discourse is valid for all the elements in the dataset. If this is not the case an indication of the homogeneity of the dataset is required. One may consider this as a quality parameter or as a specification element in the universe of discourse.

Geometry

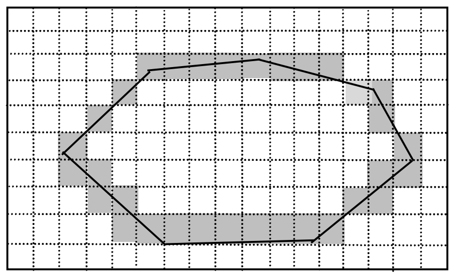
The spatial aspect in GIS is described by the geometry and is the most important aspect that distinguishes GIS from other ICT applications since it introduces more-dimensional queries. Geometry can be represented by either (see fig.7):

- vector, where point's locations are represented by co-ordinates. The connection between these points represents a line type feature (or creates a boundary between objects). The position of a point is specified by distances relative to each other or directly by co-ordinates in a specified co-ordinate reference system. The location can also be specified indirectly for instance by an address.
- raster, dividing the region of interest into a regular or irregular set of cells called pixels[2]. Here each object can be defined geometrically by a set of pixels. Obviously this is a field-based definition of the dataset, although some pixels may be empty in definition. Grid representation uses a similar representation as the raster but now the intersection points of lines carry the thematic attributes (this might also be geometric data e.g. height).

[2] abbreviation of picture element



Vector:
X_1, Y_1, X_2,Y_2, . . .
. . . , X_7, Y_7, X_1,Y_1



Raster:
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 1 1 1 1 1 1 1 1 0 0 0 0
0 0 0 0 1 0 0 0 0 0 0 0 0 1 1 0 0
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Figure 7 .
a) *vector data organisation: each line string is represented by the connection of its characteristic points carrying co-ordinates;*
b) *raster data organisation: each pixel has a row- and column number for positional definition as well as a non-metric value, e.g. 1 for the presence of line information and 0 for the absence of line information.*

Geometry is described by three elements: location, toplogy, and shape:

1. *Topology*.
   Topological relationships are spatial relationship invariant for geometric transformations such as translate, scale or rotate. Many queries use topological relationship e.g.: shortest path calculations, location of occurrences in a predefined area or selection of addresses along a road. They describe the neighbourhood relations in a GIS, based on Eulers' graph theory. For that respect it is necessary to realise that an object in GIS subdivides space into the interior of the object, the boundary and the exterior.
   Applying Euler's theory many researchers have tried to describe all topological relationships that may occur in a GIS between objects. It can be mathematically proven that for a 3-dimensional GIS only 6 neighbourhood relationships are important. i.e.: equal, inside, touch, overlap, cross and disjoint. Based on these relations a formal data structure for a GIS can be designed as in fig. 8 [Molenaar, 1989];

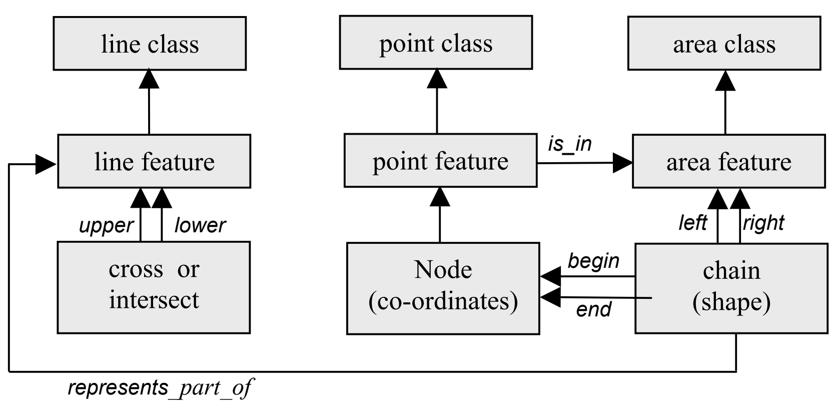

Fig. 7. Formal data structure for a 2-D GIS for vector data applying topology. [Molenaar, 199.]

2. *Location*.
   As all point-, line-, region- and volume objects in a GIS refer to point objects (see fig.8) the location in a GIS is described by the points' co-ordinates. Co-ordinates are referring to a geodetic co-ordinate system and may be defined on global, national, regional or local level. In order to ensure data communication between different types of databases, the co-ordinate definition for each subset should be known and defined in the metadata to allow for geometric transformation of one system into another. This requires enough overlapping points in either system;
3. *Shape*.
   Most GIS vector systems assume straight connection between points in a line but in fact for each connection between points, the type of interpolation is required. Besides the order of the points in the line is to be defined (sometimes this is called the 1-dimensional topological relationship, while the neighbourhood relations of region objects is called 2 dimensional topological relationship.

Infra structure

Since geographic databases become more and more available for all types of applications and because the collection of the data is very expensive, data is often commonly used. Many practitioners in the field of geographic data need to obtain the data from these sources and more frequently this is done through the Internet facilities. Also the availability and location of data is often not known. Therefor, countries are developing a geo-information infrastructure, i.e. a system open up datasets and its availability. They are stimulated by the developments in the United States of America and, in Europe, supported by EUROGI, the Umbrella Organisation for Geographic Information within Europe.

The central part of the geographic information infrastructure (GII) is a clearinghouse. The concept of a clearinghouse is taken from the banking system, where all payments during a day are stored in the clearinghouse and at the end of the day the debts that bank have towards each other are cleared by transferring the final amount of money to the respective banks.
In GII, a clearinghouse has a slightly different task: the data descriptions are made available for users, usually through the Internet. Sometimes, the clearinghouse also transfers the data and bills the customer.
So, the infrastructure that is required for GII consist of different elements:

1. *policy*.
   In order to develop a geographic information infrastructure, a policy is required for the institutes that participate in the system to offer data, as well as a pricing policy for the availability of the data and the descriptions of the datasets. Such descriptions are stored in so-called metadata. The participating organisations have to prepare these metadata files in order to offer them to potential customers. An agreement is required about the model to store and access the metadata files. In some countries the development of a GII is seen as a governmental task; in other countries this is arranged by a private organisations to which the data providers and users contribute;
2. *geo data sets*.
   Datasets that are made available for users through the GII are the basic data for them that they can enhance for their applications. Often also specific thematic data is made available through the GII. So one can distinguish *basic and thematic* datasets in the GII facility;
3. *geo information technology*.
   These are important elements for GII offering computer, software toolboxes and electronic communication facilities (networks). Especially the fast development of the communication technology creates new opportunities for GII and promotes the use of electronic devices and communication;

4. *standards*.
   In order to allow the transfer of data from the producers to the user and make the data understandable for the recipient of the data, both parties have to agree about a common structure format and data definition both for the data as well as for the metadata. For all parties that may participate in the use of data in future, should prepare such standards. This is often done in international (ISO, International Standardisation Organisation and CEN, European Committee for standardisation) or national standardisation institutes where all parties in the field geographic information can participate. A long period of participation in the standardisation process both nationally and internationally has shown to the author that the technical part of the standardisation is relatively easy to achieve in comparison to the standardisation of the object definition.
   Recently a group of system providers have founded the global private organisation Open GIS Consortium (OGC) to enable data to be used independent of data format within each of the systems. OGC operates together with the ISO and other international bodies in the field of geo-information;
5. *knowledge*.
   The continuously developments of the technology for the infrastructure and standards that become available, can only take place when the knowledge about the system and the standards is shared and distributed amongst all participants of the GII and dedicated towards their needs. Interaction between developers in the scientific and practical research institutes and the users should be strongly promoted, as well as regular education and continuous learning facilities. Also exchange of experience between data providers, data users and facilitators is necessary to customise the GII for regular use.

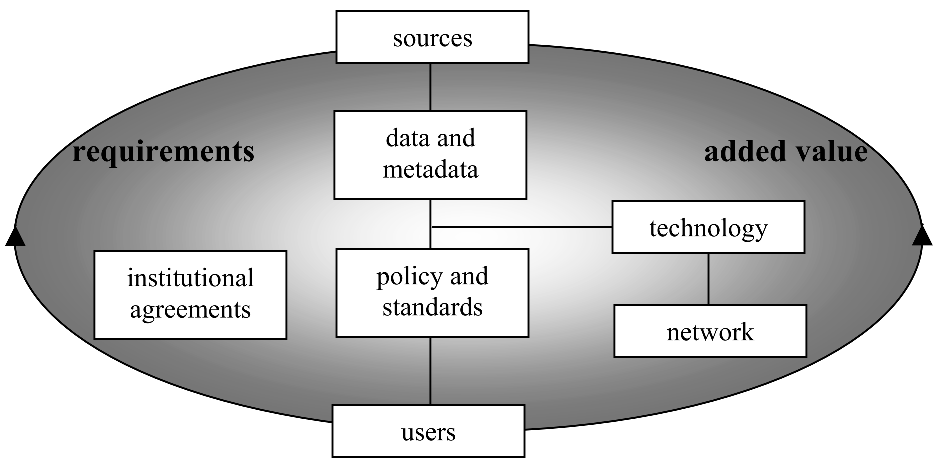

Fig.8. Components of a Geo clearinghouse.

Conclusions

Although GIS has enormous capabilities, pitfalls in appropriate application of GIS within a certain field of research, science or planning requires thorough knowledge of the systems and its capabilities and functions but also about the use of GIS in a certain application model. Besides, knowledge of the availability of basic and thematic data is required as well as the semantics of the object definitions within the dataset and its quality and potentials in relation the intended use.

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