Geographic Information Technology Training Alliance (GITTA) presents:

What is GIS?

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Content

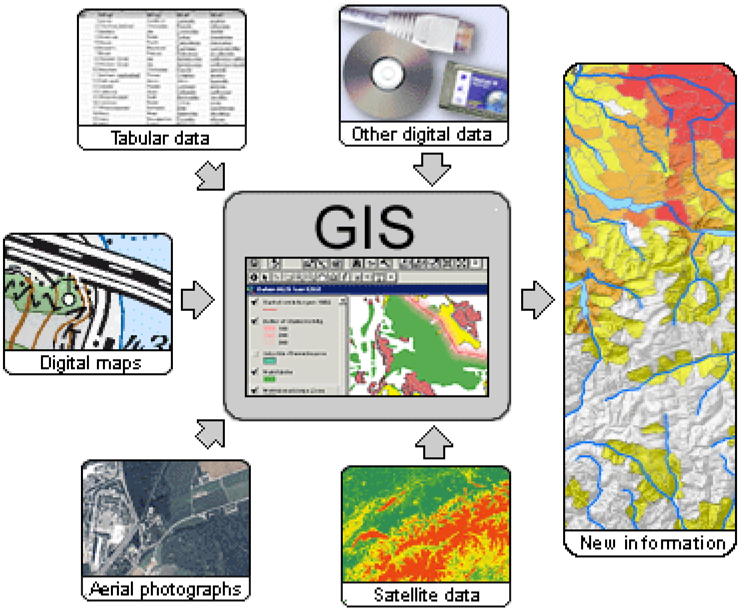
1. What is GIS?

Introduction

Living in what we call 'the age of information' or even the 'information society', the availability of global networks, large data storage capacities, high resolution sensors and fast information transmission results in vast amounts of data and information that needs to be acquired, stored, organised and structured, filtered and transmitted. 'Information systems' are becoming increasingly important not only to manage data, but also for the interpretation of data and thus the extraction of information.

In information systems, the term **data** is used for *unprocessed, uninterpreted data*. By interpreting data, meaningful **information** can be extracted. However, different - even contradicting - information can often be extracted from one data source, depending on factors like perspective, interest, additional data sources or even culture.

Thus, an information system is a tool that should be able to store, transform, query, and finally present data in various ways. It is usually capable of integrating and combining data from different sources. By analyzing and interpreting this data, the data is transformed into useful information by a user. Information systems usually run on a specific computer system or over a network and require a whole suite of software packages and hardware devices.



What makes an information system a geographic information system?

A major part of human activity and decision-making has a direct or indirect relation to space – a lot of data can more or less be linked to a location on earth (geographically referenced). In a GIS we can combine geographic data (or shortly called *geodata* [1]) with other types of information: this is what makes an information system a

[1] Geographic (referenced) data: Data that includes information on the shape, size, exact location, etc. of an object, e.g. x, y and z (altitude) coordinates of a church, vector of its layout and height of its tower.

GIS, and constitutes as the basis for all its functionality. The aim of this lesson is to give a short introduction to GIS. The focus is on the general use, on the data and on the display of information. In lesson 2, different aspects of software and hardware are discussed.

Learning Objectives

- You know what a Geographic Information System (GIS) is.
- You understand why there is no clear definition and the ambiguity in the usage of the term GIS.
- You know the fields of application for GIS and its limitations.
- You understand the difference between spatial and attribute data and know what topology is all about.

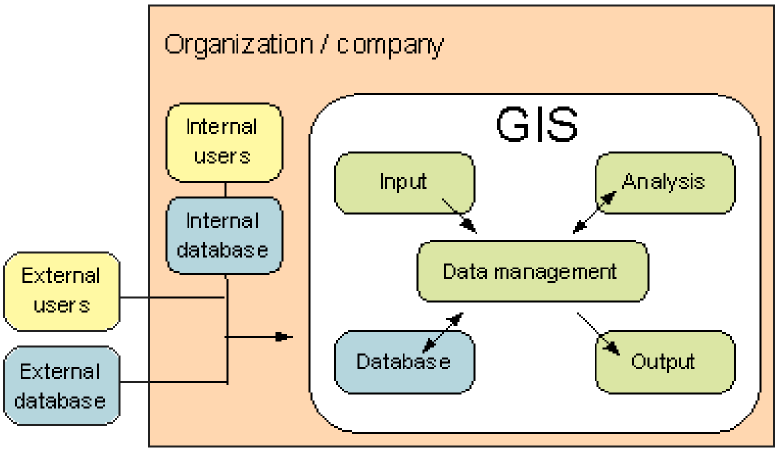
1.1. A general introduction to GIS

The definition of GIS

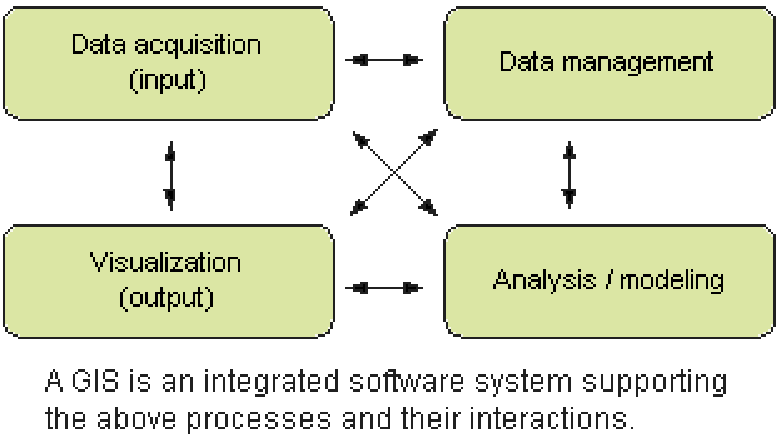
Geographic information systems are used for many different tasks and in many different fields of application. As such, a GIS often forms an interface between a variety of disciplines such as geography, information science, mathematics, surveying, or environmental science. Consequently, many different definitions about what a GIS exactly is exist and there are even lively discussions about what disciplines form the field of geographic information science. Even though the term GIS is used differently, depending on the context, some general concepts can be formulated.

Two meanings of the word GIS

There are two distinct meanings of how people use the word GIS, as shown in the two illustrations below:



A GIS is a computer system, including hardware, data, software and an application to analyze and solve a space related task (involving *geodata*).



A GIS is a type of software, either sold by a software producer or developed by a group of volunteers and distributed as *open source* [3], to analyse and solve a space related task (involving *geodata*).

In this module, we will focus on the **first definition**, but use both meanings depending on the context. We will define a GIS as a computer system including hardware, data, software, and an application designed to acquire, manage, analyze and present geographic information in many ways.

1.1.1. GIS tasks: Answering questions

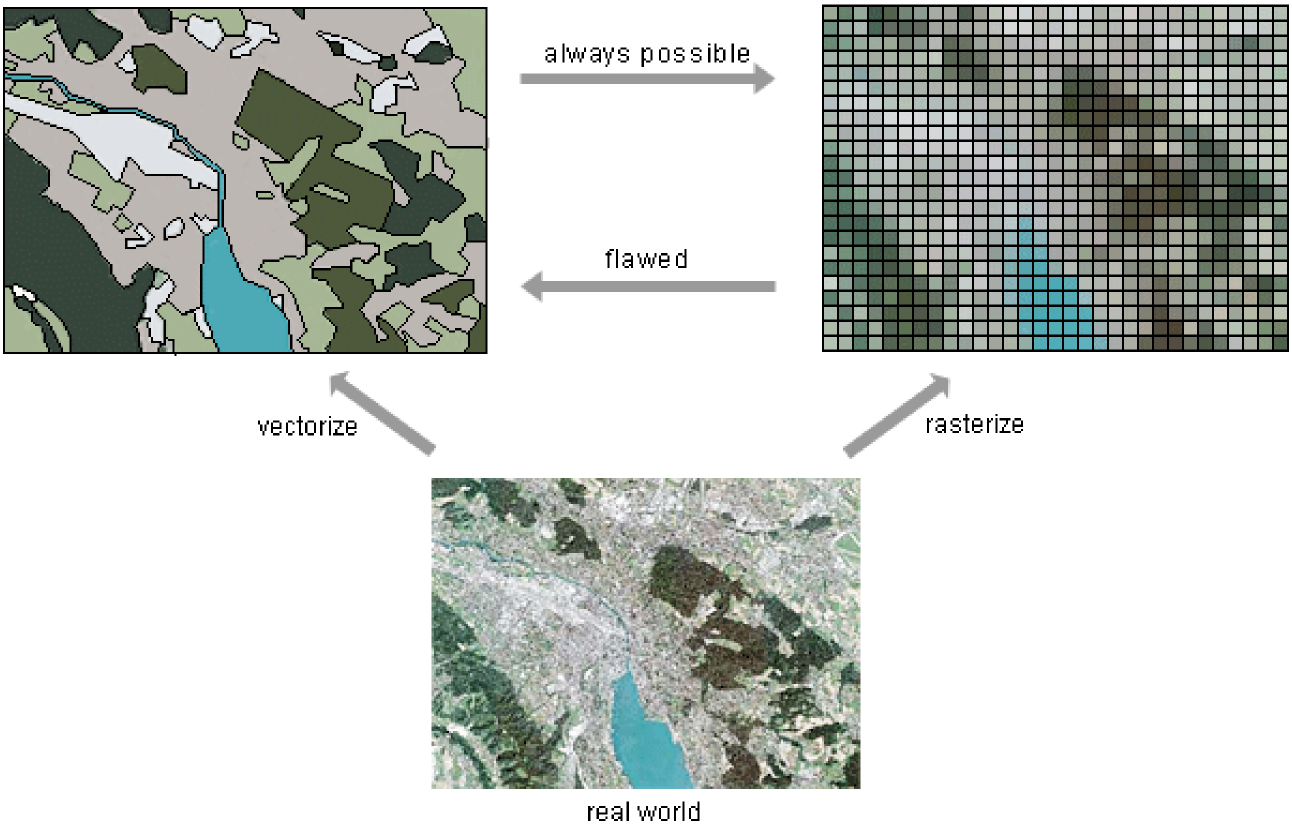
A geographic information system is used to find answers to questions that are related to space. It can be used to explore the relationships between data distributed over an area, it can search for and identify patterns that may not be apparent, and it makes it possible to link or analyze information that is difficult to associate through any other means. Thus, a GIS can use combinations of mapped variables to build and analyze new variables and present them in an understandable way. A GIS can reveal important new information that leads to better understanding of complex circumstances and thus improves decision-making.
It is typically used to answer questions similar to the following:

- **Locations**- What is at a given location or where is a specific item located?
  Where can one find oak trees in Basel-Land?
- **Trends** - What has changed since ... ?
  How has the forest cover changed since 1900 in Graubünden?
- **Patterns** - What spatial patterns exist?
  How many people live closer than 200m from a mobile antenna in Zürich?
- **Networks** – How to get to ... ?
  What is the fastest way from Bern to Lausanne via Bulle by car?
- **Modeling** – How would it happen?
  How would a forest fire extend from Leuk?
- **Decisions** - What should one do if ... ?
  If Grand Dixence burst, which areas would be affected by the water?

1.1.2. GIS tasks: managing data

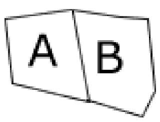
Geodata collection has a long history. Beginning in the 15th century people started to gather geographic data to create maps, especially for orientation and navigation on land and sea, later on to draw country boundaries and mark off private property and political sovereignty, eventually creating the great traditions in cartography and surveying.
In recent years however, there has been a transition from the classical, paper-based cartographic products to dynamically generated and interactive views of data on the computer. Together with the rapid evolution of information technology, application areas for GIS have widened to new fields such as traffic planning, land use, environmental science, hydrology and many more. It became possible and necessary to collect and store new kinds of data such as population numbers, temperatures, vegetation cover, addresses, etc., in a database, which today forms the core of any information system.

Data types: Raster vs. Vector
In a GIS, we can differentiate two kinds of data: spatial and attribute data. Spatial data simply consists of points in space, each stored as a pair of coordinates and if needed its height. Geometrical objects such as streets, rivers or country boundaries can then either be represented by vector data (points, lines and polygons), or by raster data (grid of pixel-filled cells). Many GIS can handle vector and raster data to give you the advantage of both. The two data types can be transformed into each other, although the conversion usually involves a certain loss of precision and information.

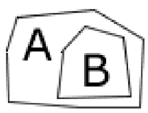


Relation in space: Topology

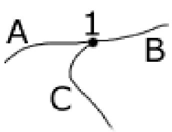
Often, we are not only interested in where real-world objects are located and how they are represented. We also want to know about their spatial relationships, e.g. their topology:



Adjacency: What is next to what?
Which parcels of land are adjacent to Zurich Airport and have already been developed?



Containment / Proximity: What is enclosed by what or how close is something to something else?
Which buildings in Bern are inside the identified flood plains and hence susceptible to flooding by the Aare?



Connectivity: What is linked to what?
Which river sections are downstream from Basel and hence likely to be polluted by an accident in the chemical industry?

While a computer-aided mapping system may represent a road simply as a line (arc/segment), a GIS may also recognize that road as the boundary between two buildings and two other roads. This allows for example "path finding" operations.

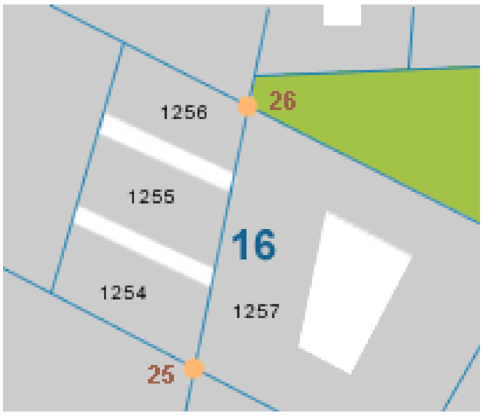


table1

ArcId	From Node	To Node
16	25	26
17	...	...
18	...	...

table2

ArcId	x,y coordinates
16	(4,8) (47,10)
17	...
18	...

Segment 16 (a street) starts at node 25 (e.g. a crossing) and ends at node 26 (e.g. another crossing). On its left side it is adjacent to the polygons 1254, 1255, and 1256 (buildings). On its right side is polygon 1257 (another building). So, we regard a segment not only as a simple line, but as a link between two elements (the crossings) and adjacent to other elements (the buildings).

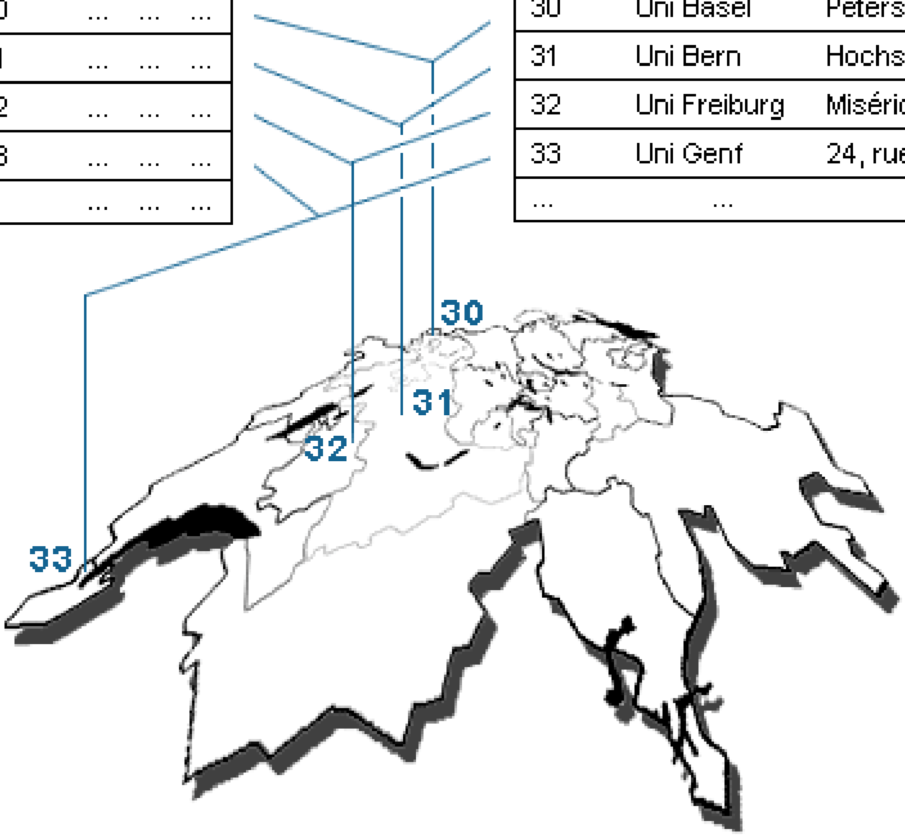
Any other non-spatial data is considered as attribute or thematic data. Attribute data is always stored with a reference to the spatial data. The following example illustrates this concept with universities. They are represented here by single point locations. In a single record, each point has associated with it not only its exact location but also information about the university, such as its name, institutes, number of students, and so forth.

table for spatial data

PointId	x	y	z
30	...	...	...
31	...	...	...
32	...	...	...
33	...	...	...
...	...	...	...

table for attribute data

PointId	Name	Address
30	Uni Basel	Petersgraben 35
31	Uni Bern	Hochschulstrasse 4
32	Uni Freiburg	Miséricorde
33	Uni Genf	24, rue du Général-Dufour
...	...	...



Acquiring data

Before any data can be managed, analysed, and visualized, it has to be acquired. Geographic and related attribute data can be either collected in-house or purchased from a federal or commercial data provider. For a long time, capturing digital data ment digitizing it manually from existing paper-maps using digitizer tablets and a mouse. In general, manual digitizing is a very work-intensive and error prone method, and the data quality is (in the best case) just as good as the map that was digitized. Nowadays, software tools that automatically extract features from satellite images, aerial photographs or already existing maps are gradually replacing what has traditionally been a very time-consuming and expensive digitizing process.

1.1.3. GIS tasks: visualising information

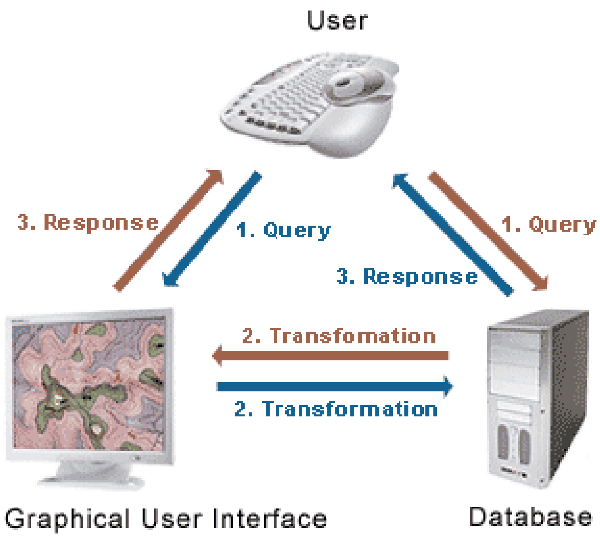


Illustration after (Bill 1999)

People visualize by nature. An image based on a visualisation of geodata such as a map or an animation is far easier to understand than the same information provided in text or a table. Visualisation is used to reduce complexity and it enables you to focus on the selected key features, the purpose of the information. It helps you to understand complex processes; to make decisions or explain what otherwise could be cluttered by details. Maps have traditionally been used to represent real-world objects and as a navigation aid to explore the earth. A GIS offers many tools to produce and display not only maps, but also 2D- and 3D models, simulations and other cartographic products. The output is often not static; you can interact with the visual to create dynamic views of the data. This could be for example simple zooming functions, showing the shortest route from A to B, or more complex modeling and simulating for disaster prevention.

Zooming versus scaling

What is the difference between simple scaling and GIS powered zooming ? Use the button zooming / scaling to switch between these two modes and find it out. Use the + / - buttons to zoom in / zoom out or to scale in / scale out. Use the reset button to restart.

Only pictures can be viewed in the PDF version! For Flash etc. see online version. Only screenshots of animations will be displayed. [link]

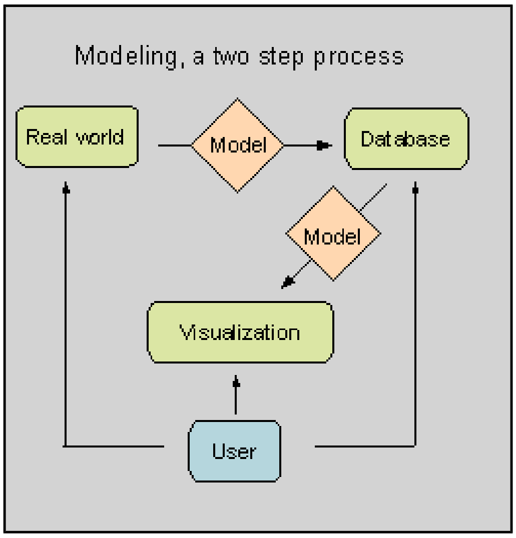
www.gis.zh.ch
GIS of canton Zürich with link to GIS-Browser.
www.ag.ch/agis
GIS of canton Aargau with links to interactive maps.
www.gis-luzern.ch
GIS of canton Luzern with link to map server.
www.mappy.de

Online route planner and interactive street maps for Europe, also for pda's and mobile phones.
www.map24.com
Online route planner and interactive street maps for Europe. Very fast.

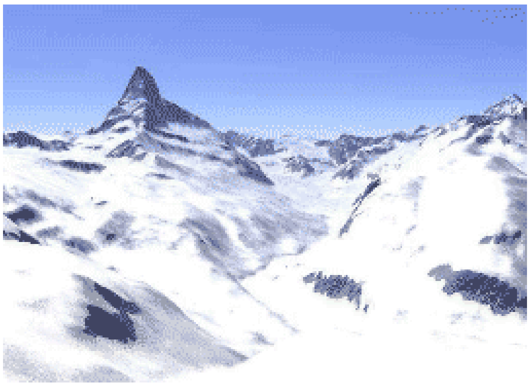
Modeling and simulation

Most phenomena in nature are too complex to be represented in a GIS on a one to one basis. Therefore, you will have to simplify the real world and build your own data model according to the problem or task by concentrating on the essentials.

- Analyse the real world: Identify spatial objects and their relationships.
- Develop a clear and logical flowchart: Break down your problem according to your quest.
- Organize and structure the data: Bring your data into a form your software can understand and that allows for further analysis.



The next step in the whole modeling process will be the creation of the visualisation model. It defines how and which part of the data model should be displayed.



Visualisation of a digital elevation model (DEM) of the Matterhorn. Source: (Bundesamt für Landestopografie)

Simulation of pollutants through a stream system. Source: (U.S. Geological Survey)

Simulation adds the element of time to a map. Not only the as-is can be showed, also past or future situations can be visualized using data models. This way the GIS can show different alternatives of a situation, which can be examined to help make better decisions. It can also make processes visible, that extend over days, months, and years, such as the drying out of lakes or the change in vegetation cover.

1.2. Test your knowledge

By answering the following questions, you can test your knowledge about this unit. The questions will be presented to you in random order. As soon as you complete the questions on one page, you will gain access to the next page (the next button turns dark blue). After answering all questions your score will be shown. You can press the button "Show Answer" to display an explanation. Actually, you can do so any time, but this would be cheating ;-). Press the "Reset" button to start over.

Consider the questions only as general statements when answering them, of course you can always find an exception to the question.

Only pictures can be viewed in the PDF version! For Flash etc. see online version. Only screenshots of animations will be displayed. [link]

1.3. Summary

Definitions of what a GIS is range from a 'simple' software package designed to acquire, manage, analyze and present geographic information in many ways to a 'complex' computer system including hardware, peripherals, data, software, and applications. A GIS is best defined by the type of questions it should be able to answer:

- Location - What is at a given location?
- Condition - Where does something occur?
- Trends - What has changed since …?
- Patterns - What spatial patterns exist?
- Modeling - What happens if… ?

Besides the task of answering space related questions a GIS has a number of prerequisites, such as capabilities to import, manage and visualise different data types such as raster and vector data of different origin and different format. One of the most important tasks for a GIS is probably visualisation of information that can be a simple visualisation of spatial relations (the topology) or more complex visualisation of model results or 3D simulations.

1.4. Recommended Reading

- **Buckley D.J.**. *The GIS Primer* [online]. Available from: http://www.innovativegis.com/basis/primer/primer.html [Accessed 2005-01-21].

  An introduction to GIS and related issues
- **GIS Development Pvt. Ltd.**. *GIS Development: The Geospatial Resource Portal* [online]. Available from: http://www.gisdevelopment.net/ [Accessed 2005-01-21].

  Good starting point to look for terms, definitions, data, tools and other resources...
- **Peterson M.P.**. *Geographic Information Systems* [online]. Available from: http://maps.unomaha.edu/Peterson/gis/ [Accessed 2005-01-21].

  Course materials and more from Dr. M.P. Peterson at Edinburgh University

1.5. Glossary

geodata:
: Geographic (referenced) data: Data that includes information on the shape, size, exact location, etc. of an object, e.g. x, y and z (altitude) coordinates of a church, vector of its layout and height of its tower.

open source:
: Open source is a term used for software with freely distributed and accessible source code (the programme code). Open source software is often distributed under the GNU General Public License (GPL).

1.6. Bibliography

- **Bill, R.**, 1999. *Grundlagen der Geo-Informationssysteme*. Karlsruhe: Wichmann Verlag.
- **Buckley D.J.**. *The GIS Primer* [online]. Available from: http://www.innovativegis.com/basis/primer/primer.html [Accessed 2005-01-21].
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