Geographic Information Technology Training Alliance (GITTA) presents:

Spatial Queries

Responsible persons: Claudia Dolci, Dante Salvini, Robert Weibel, Samuel Wiesmann

Table Of Content

1. Spatial Queries

PLEASE NOTE: this lesson has been translated from German to English. However, some of the figures are still in German.

The aim of spatial queries and their analysis is to detect spatial relationships between elements of one or more subjects, in order to locate spatial objects. The results of such analysis can be used in decision making. This lesson is divided into four units. An introduction to the subject and the most important terms are provided in the first unit. These terms will be discussed in more detail in the other units.

Learning Objectives

- You know the objects of queries and are able to establish a connection between database structure and query possibilities.
- You are able to formulate a thematic query and to execute a simple and a complex query.
- You understand the basics of a geometric query and know how to perform the most important queries.
- You know the topological relationships between the objects and are able to formulate a topological query.

1.1. Introduction to spatial queries

The database structure, which is included in a GIS, enables the logical, *consistent* [1] and ordered storage and management of data. Both thematic and geometric information are stored in the form of tables. In the discipline of geoinformation, the term data analysis includes all those investigations, queries, evaluations, etc., which are carried out on structured and stored spatial data. When a query is performed to obtain and answer to a spatial question, the data are accessed through the basic elements of this structure which is made up of tables, fields, data sets, values and connections.

Citation:
"*The deduction of new information from existing spatial data is one of the main tasks of a geoinformation system.*
Spatial analysis comprises analysis and synthesis of spatial data to a unity [...] Every spatial analysis implies the professional interpretation of the resuslts." (Bill 1999)

Example of a query:
"Which proportion of the inhabitants of Zürich lives more than 200m away from a public transport stop?"

1.1.1. The information system

An information system is a question#answer system based on a data set. This system contains tools for the computer based analysis and handling of information. Such a system is called geographic information system (GIS) if the data are geographically referenced (Carosio 2000). A GIS is composed of various individual components. Some of these functions are basic, while others are more complicated or required for special applications. The user interface, query functions and the data management system play an important role. The user interface enables the user to communicate with the system. It allows users to start operations, query information, etc. Via the user interface, analysis functions can be executed through accessing the data. Data access and data management in general is controlled by the database management system.
Have a look at the following illustration to get an idea of information systems:

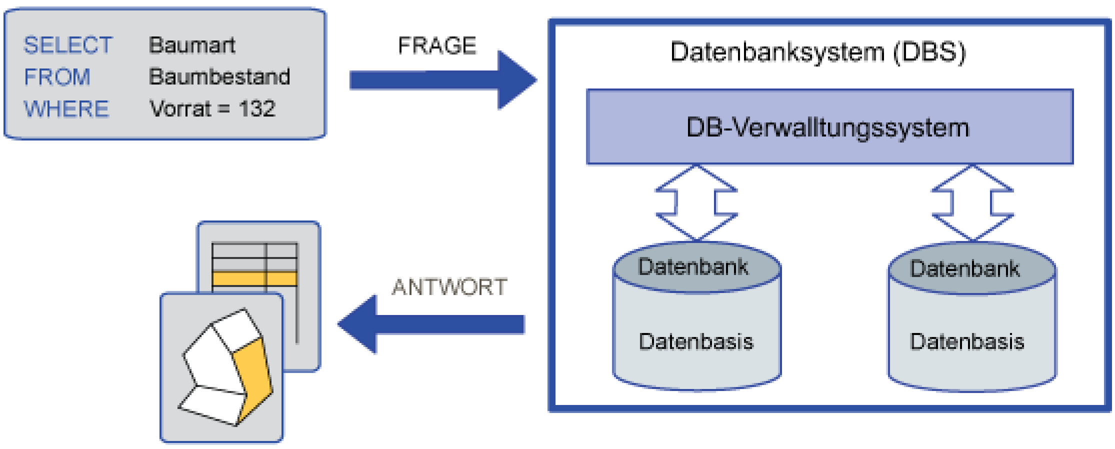


Fig. A: Architecture of a database

[1] Gewährleisten der Widerspruchsfreiheit innerhalb einer Datenbank; d. h., dass der Inhalt einer Datenbank alle vordefinierten Konsistenzbedingungen ("Constraints") erfüllt.

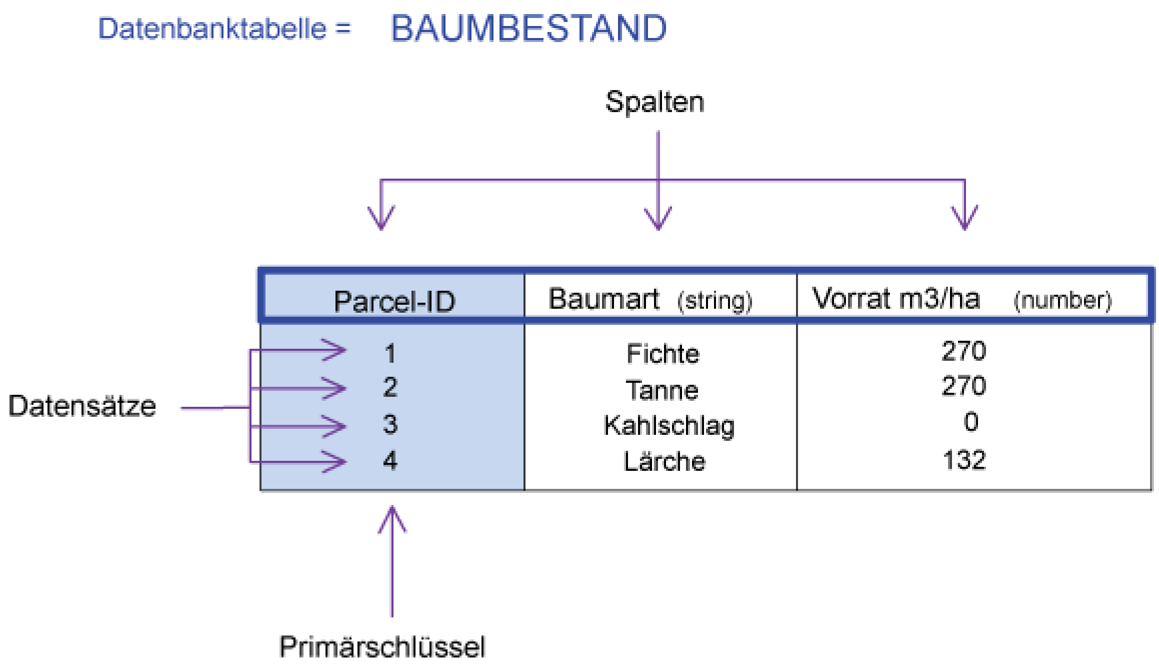


Fig. B: Structure of a table

1.1.2. The basic components of geographical information

A commercial GIS stores spatial data and its attributes in separate data files in which corresponding lines are linked by a unique identification number. This identification number allows a GIS to search for attribute values and to display them based on spatial query criteria, and vice versa.

In the geometric representation of an object, information about its attributes can be derived by selecting this object in a GIS. There is also the possibility to identify an object by its geometric representation by selecting its entry in the attribute table.

The data structure comprises the connection of thematic and geometric information. The geometry is expressed in the spatial reference. A spatial reference is assigned to all the objects in a greater or lesser extent. Spatial references describe the location and extent of this geographic information. In addition to the metric properties (geometry), topological properties should also be mentioned. Topological properties are expressed by information about e.g. relations of neighborhood (what object is neighboring?), containedness (does an object contain other objects?), overlap (is an object overlapped by other objects?), etc. In addition to geometric and topological properties, thematic properties are also assigned to each object. They are stored in tables. The geometric and thematic information affect each other. These so#called objects are subject to temporal changes. (Bartelme 2000).

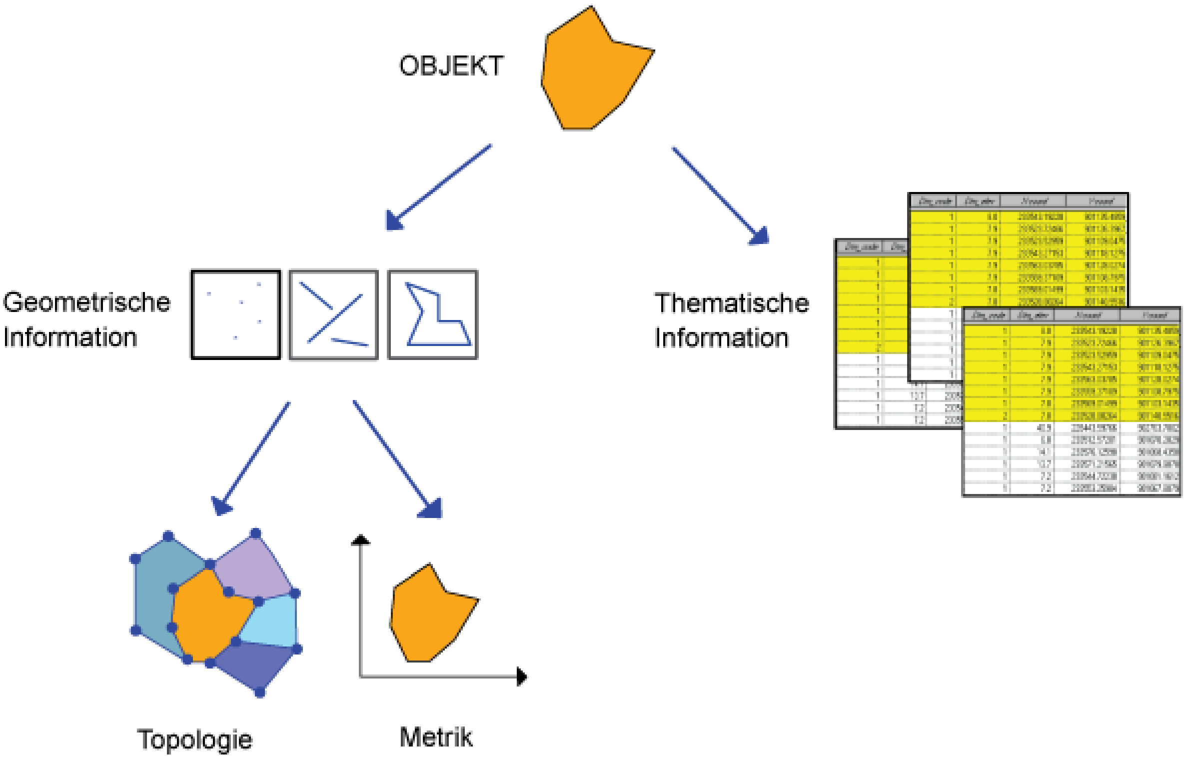
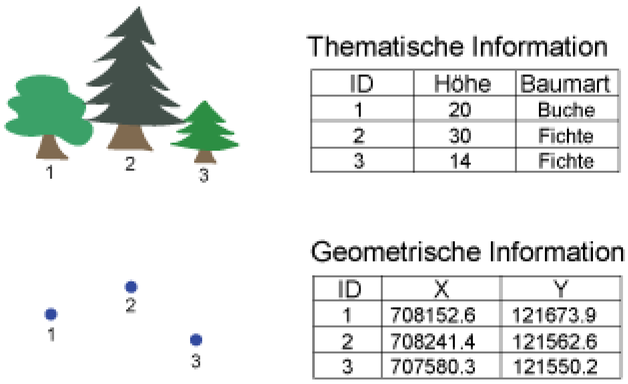
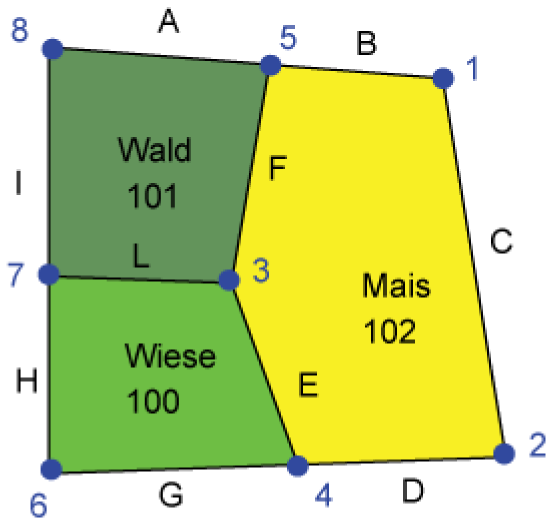


Fig. C: Basic components of a GIS

Example 1:



Example 2:



Thematische Information

ID	Name	Ertrag
100	Wiese	....
101	Wald	....
102	Mais	....

Geometrische Information

ID	Perimeter	Fläche
100	....	....
101	....	....
102	....	....

Geometrische Information

ID	X	Y
1	708241.4	121673.9
2	707580.3	121562.6
3	709010.3	121550.2
4	708875.8	121976.6
5	710405.6	120500.5
6	721512.5	120574.0
7	723649.2	1206457
8	723634.4	120788.2

Topologische Information

ID	FROM NODE	TO NODE	LEFT POLYGON	RIGHT POLYGON	LENGTH
A	8	5	outside	101	....
B	5	1	outside	102	....
C	1	2	outside	102	....
D	2	4	outside	102	
E	4	3	100	102	
F	3	5	101	102	
G	4	6	outside	100	
H	6	7	outside	100	
I	7	8	outside	101	
L	8	3	101	100	

1.1.3. Query classification

The aim of spatial selection and analysis is to determine spatial relationships between one or more subjects in order to locate those elements in space. The results can then be used for decision#making. Performing a query, a number of criteria have to be formulated. To do so, the following approaches are possible:

- Thematic query:
  Selection of all objects which achieve the required conditions (attributes). E.g.: "Select all spruce trees."
- Geometric query:
  Selection of all objects which achieve the required spatial conditions. E.g.: "Select all the houses that are located less than 250 m away from the river".
- Topological query:
  Selection of all objects which achieve the required conditions regarding the spatial relations between the objects. For example: "Select all the buildings that are lying in zone 1".

Subquery

Queries can be performed on the entire data set or a subset of the data. Subsets are generated via queries. A subquery is a `SELECT` statement that is incorporated in a `SELECT`, `SELECT...INTO` , `INSERT...INTO` , `DELETE` , `UPDATE` statement or in another subquery. A subquery is composed of three parts.

Part	Description
Comparison	predicate and a comparison operator that compares the predicate with the result of the subquery.
Expression	An expression that is searched for in the result of the subquery.
SQL statement	A SELECT statement according to the usual format of the SELECT statement. It must be in parentheses.

Example:

```
SELECT * FROM product WHERE product-ID IN (SELECT product-ID FROM
 orders WHERE discount >= .25);
```

A query can be classified in two ways, based on the result:

- Direct query:
  Data are accessed interactively by the user or by an application program. Thus, a subset can be extracted, while the original data remains unchanged. The selection commands can be entered in command lines or query masks. More complex queries that require multiple single line commands can be prepared as sequences of command lines (batch, macro). In order to formulate queries, there is a formal query language. Many GIS support *SQL* [2] (Structured Query Language) as query language for thematic topics (see unit "Thematic Selection").
- Manipulation:
  By manipulating, new geographic information elements can be created. These new elements can be used for analysis purpose in further steps. In general, the new objects have to be previously conceptually modeled , and their data structure has to be implemented in the GIS. Some GIS can generate a minimal data structure (without thematic attributes) automatically. New information can be generated combining different objects. They can be used for further analysis.

[2] "Acronym for Structured Query Language. A syntax for retrieving and manipulating data from a relational database. SQL has become an industry standard query language in most relational database management systems" , e.g. Oracle, DB2, Access, etc.

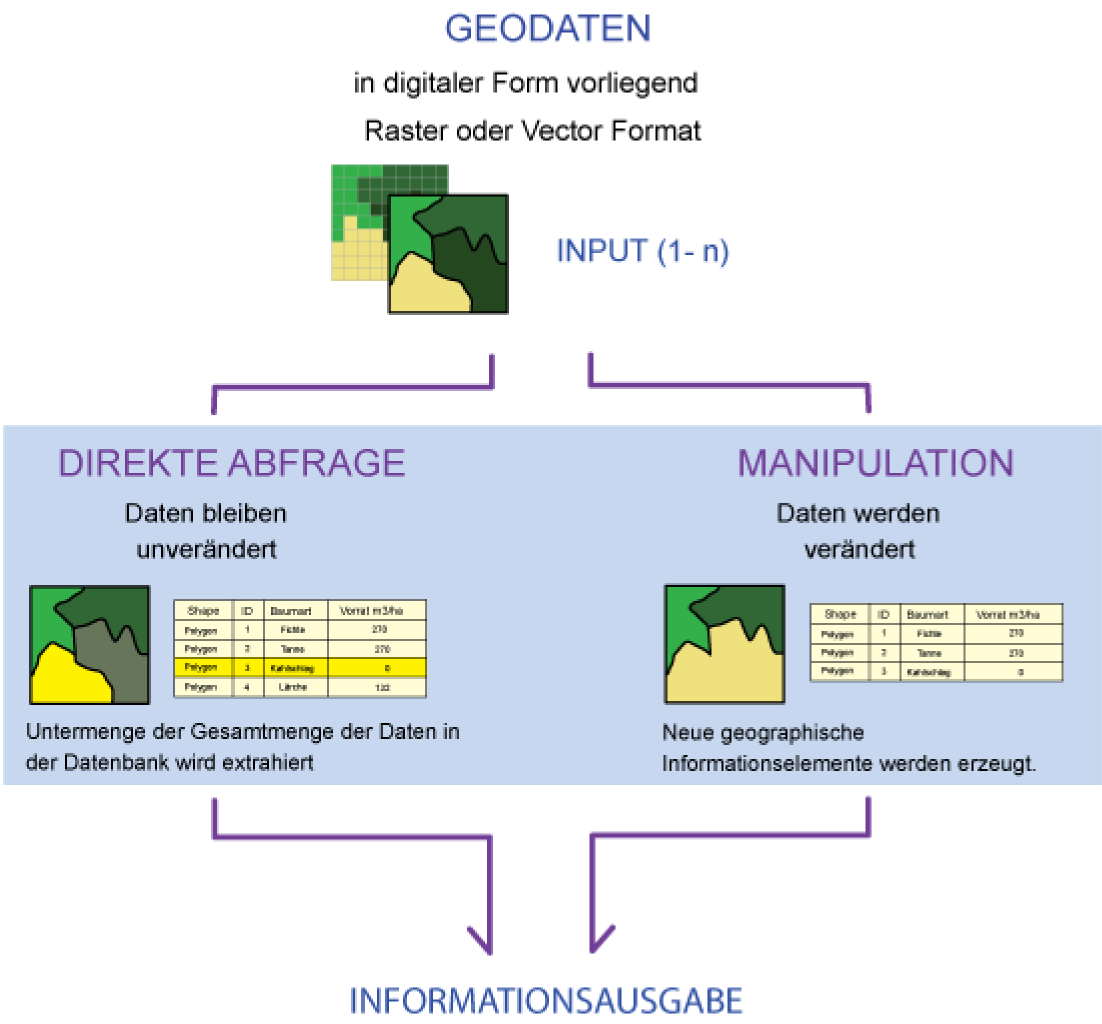


Fig. D: Classification of the query into direct query and manipulation

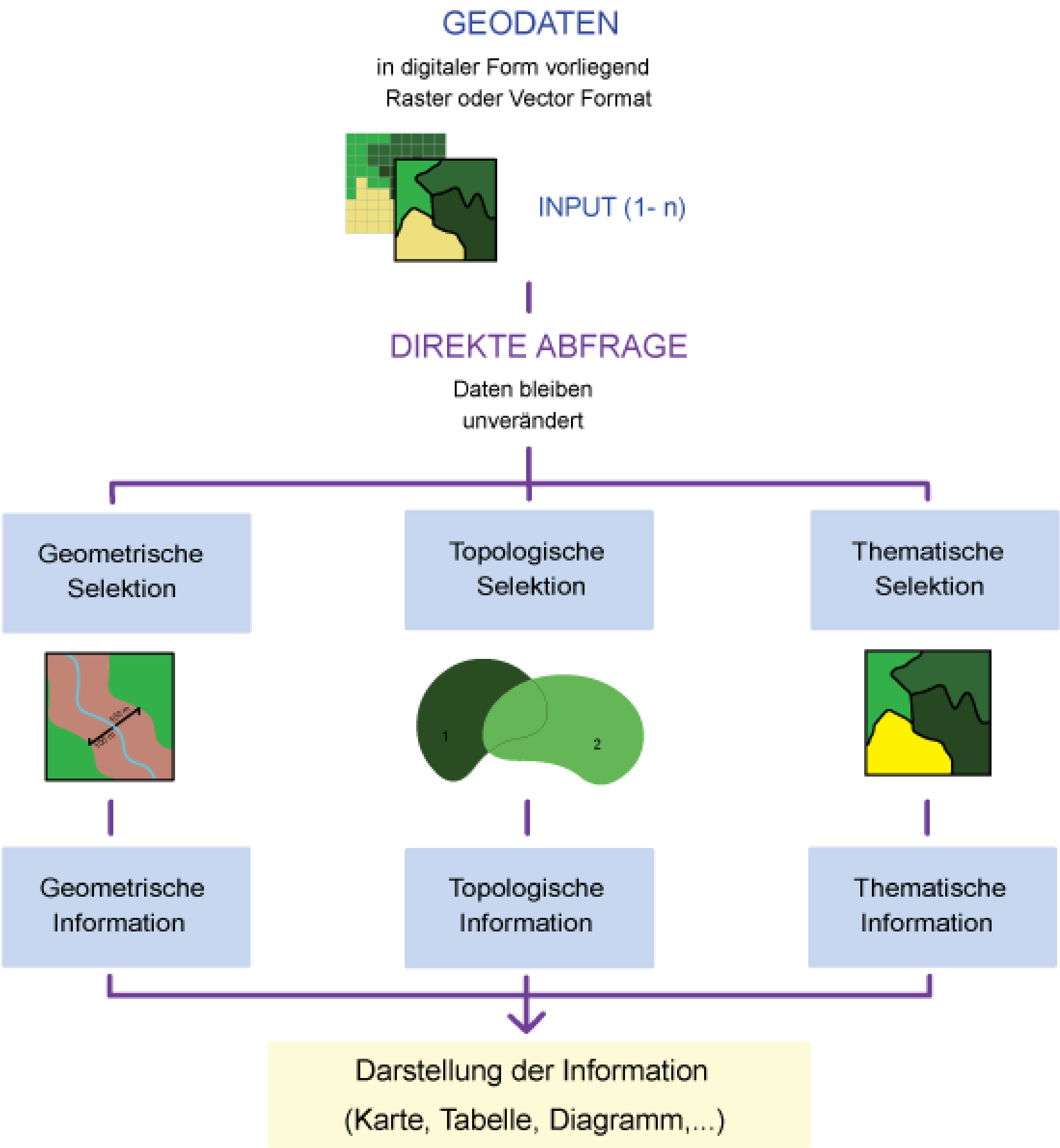


Fig. E: Splitting the direct query

1.1.4. Input / Output of a query

A query relates to specific datasets and the data type defines whether a certain query is possible or not. The common data types in a GIS are vector and raster and also tables. Thus, the queries on raster data are different than the queries on vector data, although the question to be answered is the same. The number of data sets included into the query also plays a role. The query can refer to a single or multiple data sets. The relationships between the data involved in the query are given via the *topology* [3] (geometry) or the tables (theme). Tables can also be related to each other. The content of the tables can be linked via key attributes. Thus, a query can be performed over several linked tables.

BAUMBESTAND		
PARCEL-ID	Baumart	Vorrat m3/ha
1	Fichte	270
2	Tanne	270
3	Kahlschlag	0
4	Lärche	132

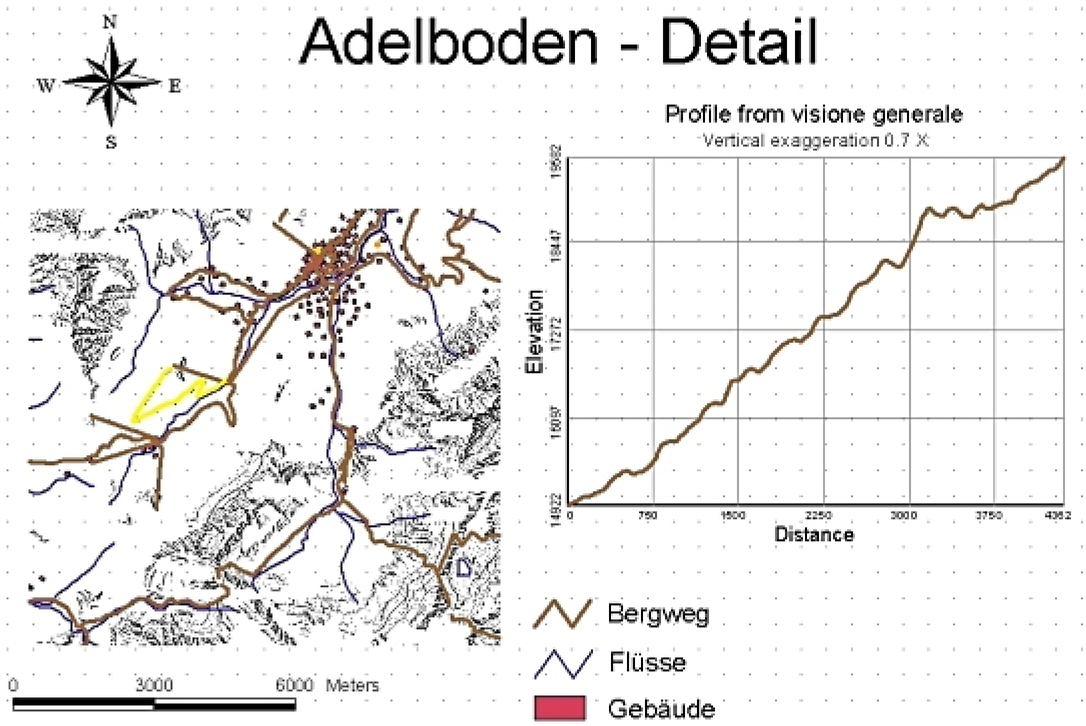
m — 1

HOLZBEDARF	
Baumart	Bedarf %
Fichte	5
Tanne	4
Lärche	2

Fig. F: Linked tables

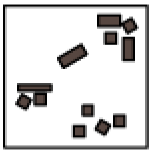
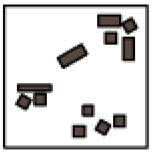
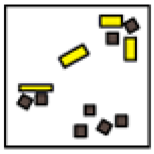
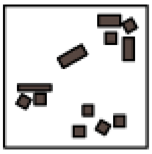
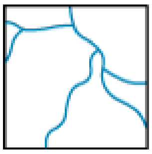
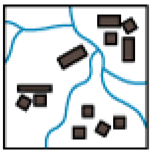
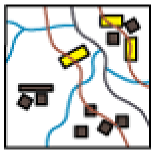
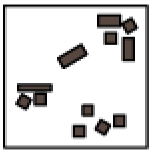
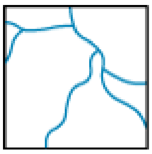
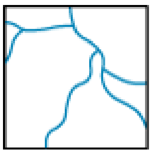
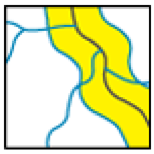
The result of a query can be presented in different forms. The result should be presented in a form which is easy for the user to read. Normally, the results are presented as maps, tables, or figures, or in another format which allows data sharing. The following are examples of data presentation:

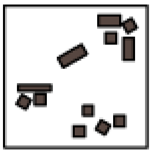
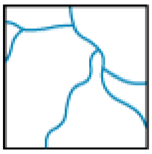
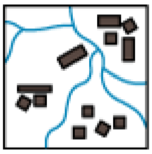
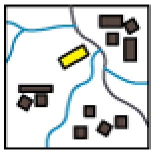
1. Digital data transfer
2. Interactive graphics on screen
3. Tables, reports, and similar representations
4. Passive graphics in form of maps



[3] Die Topologie beschäftigt sich mit den räumlichen und strukturellen Eigenschaften der geometrischen Objekte unabhängig von ihrer Ausdehnung und ihrer Form. Die topologischen Eigenschaften äussern sich in Beziehung der Nachbarschaft, des Enthaltenseins, der Überschneidung und Ähnlichem.

Some examples

<table>
<tr><th>Layer 1</th><th>Layer 2</th><th>Inputs</th><th>Query</th><th>Type</th><th>Res. table</th><th>Res. graphic</th></tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Find the buildings, which have an area of more than 100m^2.</td>
<td>THEM</td>
<td><table><tr><th>Shape</th><th>ID</th><th>AREA</th></tr><tr><td>Polygon</td><td>1</td><td>105</td></tr><tr><td>Polygon</td><td>2</td><td>50</td></tr><tr><td>Polygon</td><td>3</td><td>50</td></tr><tr><td>Polygon</td><td>4</td><td>110</td></tr><tr><td>Polygon</td><td>5</td><td>110</td></tr><tr><td>Polygon</td><td>6</td><td>115</td></tr><tr><td>Polygon</td><td>7</td><td>50</td></tr><tr><td>Polygon</td><td>8</td><td>50</td></tr><tr><td>Polygon</td><td>9</td><td>50</td></tr><tr><td>Polygon</td><td>10</td><td>50</td></tr><tr><td>Polygon</td><td>11</td><td>50</td></tr><tr><td>Polygon</td><td>12</td><td>50</td></tr></table></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Find the buildings, which have an area of more than 100m^2 and which are within a distance of 100m to Adelriver.</td>
<td>GEOM + THEM</td>
<td><table><tr><th>Shape</th><th>ID</th><th>AREA</th></tr><tr><td>Polygon</td><td>1</td><td>105</td></tr><tr><td>Polygon</td><td>2</td><td>50</td></tr><tr><td>Polygon</td><td>3</td><td>50</td></tr><tr><td>Polygon</td><td>4</td><td>110</td></tr><tr><td>Polygon</td><td>5</td><td>110</td></tr><tr><td>Polygon</td><td>6</td><td>115</td></tr><tr><td>Polygon</td><td>7</td><td>50</td></tr><tr><td>Polygon</td><td>8</td><td>50</td></tr><tr><td>Polygon</td><td>9</td><td>50</td></tr><tr><td>Polygon</td><td>10</td><td>50</td></tr><tr><td>Polygon</td><td>11</td><td>50</td></tr><tr><td>Polygon</td><td>12</td><td>50</td></tr></table></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Find the buildings, which are completely within the forest.</td>
<td>TOPO</td>
<td><table><tr><th>Shape</th><th>ID</th><th>AREA</th></tr><tr><td>Polygon</td><td>1</td><td>105</td></tr><tr><td>Polygon</td><td>2</td><td>50</td></tr><tr><td>Polygon</td><td>3</td><td>50</td></tr><tr><td>Polygon</td><td>4</td><td>110</td></tr><tr><td>Polygon</td><td>5</td><td>110</td></tr><tr><td>Polygon</td><td>6</td><td>115</td></tr><tr><td>Polygon</td><td>7</td><td>50</td></tr><tr><td>Polygon</td><td>8</td><td>50</td></tr><tr><td>Polygon</td><td>9</td><td>50</td></tr><tr><td>Polygon</td><td>10</td><td>50</td></tr><tr><td>Polygon</td><td>11</td><td>50</td></tr><tr><td>Polygon</td><td>12</td><td>50</td></tr></table></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Find the area, which is within a distance of 100 m to Adelriver.</td>
<td>GEOM</td>
<td><table><tr><th>Shape</th><th>BUFFDIS</th></tr><tr><td>Polygon</td><td>100</td></tr></table></td>
<td></td>
</tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td></td>
<td>Find the building, which is closest to Adelriver.</td>
<td>GEOM</td>
<td>
<table>
<tr><th>Shape</th><th>ID</th><th>AREA</th></tr>
<tr><td>Polygon</td><td>1</td><td>105</td></tr>
<tr><td>Polygon</td><td>2</td><td>50</td></tr>
<tr><td>Polygon</td><td>3</td><td>50</td></tr>
<tr><td>Polygon</td><td>4</td><td>110</td></tr>
<tr><td>Polygon</td><td>5</td><td>110</td></tr>
<tr><td>Polygon</td><td>6</td><td>115</td></tr>
<tr><td>Polygon</td><td>7</td><td>50</td></tr>
<tr><td>Polygon</td><td>8</td><td>50</td></tr>
<tr><td>Polygon</td><td>9</td><td>50</td></tr>
<tr><td>Polygon</td><td>10</td><td>50</td></tr>
<tr><td>Polygon</td><td>11</td><td>50</td></tr>
<tr><td>Polygon</td><td>12</td><td>50</td></tr>
</table>
</td>
<td></td>
</tr>
</table>

Exercise
What does the spatial information in a GIS mainly consist of?

1.1.5. Questions

Question 1
How can space related information be divided?
Question 2
Which approaches can be used to formulate a query?
Question 3
Describe the inputs which should be used to answer the following questions and what would the outputs look like:
"Find all buildings which are located on parcels with a minimal area of 1000 m^2 *and a distance of more than 250m to the highway".*

1.2. Thematic query

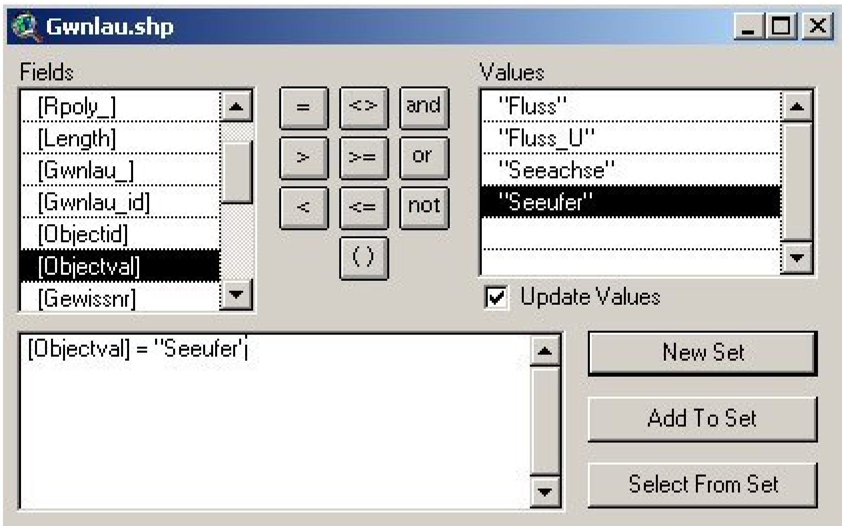
Thematic *queries* [4] result in the selection of thematic information. This process is comparable to a query of a conventional database, whose data have no spatial reference.

Query language

In a GIS, queries are performed either with *SQL* or internal query languages. In a standard GIS the commands are directly entered; in contrast, in a desktop GIS, the commands have to be selected using a dialogue system. The functionalities of SQL are explained in the "Database Management and Systems Module" (lesson 4: **Structured Query Language SQL**).

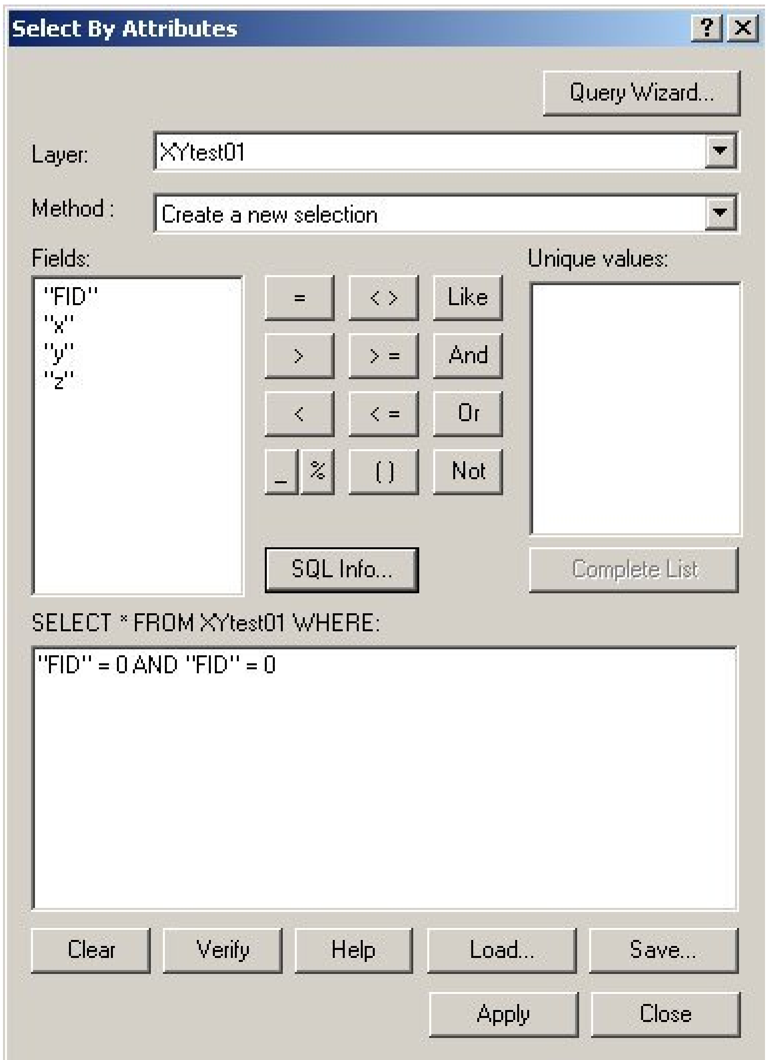
In the following examples, some user#friendly interfaces for SQL formulations of thematic queries are shown. With a few clicks the desired SQL commands are compiled. Behind the interface, the SQL syntax is used to query the database.

Example 1: ArcView Interface



Example 2: ArcGIS Interface

[4] Die Abfrage ermittelt räumliche Beziehungen zwischen Elementen eines oder mehrerer Themen, um auf dieser Basis eine Lokalisierung von Objekten zu erreichen. Die Analyseergebnisse können dann bei konkreten Fragestellungen zur Entscheidungsfindung beitragen.



Query operators

A particular feature that distinguishes a GIS is the possibility to query specific thematic information about selected objects. The thematic query relies on the analysis of technical data (attribute data). The query is performed using adequate selecting operators. In the following, three categories of *operators* [5] are presented:

- Relational operators: Besides the equal sign, relational operators can be used to formulate queries as well.
- Arithmetic operators: These operators are used for numeric attributes. E.g. there is the possibility to calculate the mean of an attribute or the sum of attribute values from a series of objects.
- Logic operators: Conditions are formulated with logic operators. The semantics (meaning) of these operators are similar to the meaning "AND", "OR" etc.

[5] In search algorithms, operators enable the logical conjunction of search items using keywords like AND, OR, and NOT.

1.2.1. Relational operators

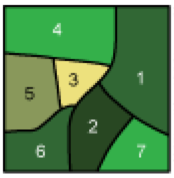
The relational operators are not only used for numeric attributes, but also for text attributes and other data types. The comparisons "greater than", "less than" etc. are related to the position of an "alphabetical" order used in a computer.

Relational operators	sometimes, other spellings are used
=	EQ (equal to)
>	GT (greater than)
>=	GE (greater than or equal to)
<	LT (less than)
<=	LE (less than or equal to)
<>	NE (not equal to)

SQL provides the following additional functions for analysis (aggregate functions):

- Avg function (average)
- Count function (number)
- Min, Max function (minimum, maximum)
- StDev, StDevP function (standard deviation, standard deviation of the population)
- Sum function (sum)
- Var, VarP function (variance, variance of the population)

An example - relational operators
INPUT

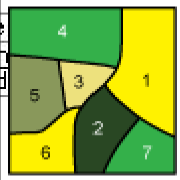


Graphic

Shape	ID	Baumart	Vorrat_m^3/ha	Bodentyp
Polygon	1	Fichte	250	Braunerde
Polygon	2	Tanne	250	Pseudogley
Polygon	3	Kahlschlag	0	Braunerde
Polygon	4	Lärche	120	Redzina
Polygon	5	Buche	300	Lithosol
Polygon	6	Fichte	130	Podzol
Polygon	7	Lärche	100	Redzina

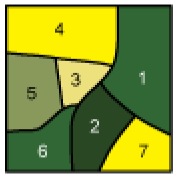
Table "Parcels: tree species (Baumart), stock (Vorrat), and soil type (Bodentyp)"

QUERY AND RESULTS

<table>
<tr><th>SQL operator</th><th>Result: table</th><th>Result: graphic</th></tr>
<tr><td><code>SELECT * FROM Parzelle WHERE Baumart = 'Fichte';</code></td><td>
<table>
<tr><th>Shape</th><th>ID</th><th>Baumart</th><th>Vorrat</th><th>Bode</th></tr>
<tr><td>Polygon</td><td>1</td><td>Fichte</td><td>250</td><td>Braun</td></tr>
<tr><td>Polygon</td><td>6</td><td>Fichte</td><td>130</td><td>Pod</td></tr>
</table>
</td><td>
</td></tr>
</table>

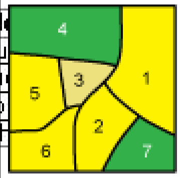
```
SELECT Baumart, Vorrat,
  Bodentyp FROM Parzell
 WHERE Bodentyp = 'Redzina';
```

Baumart	Vorrat	Bodentyp
Lärche	120	Redzina
Lärche	100	Redzina



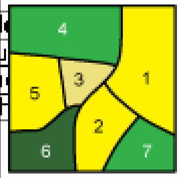

```
SELECT * FROM Parzelle WHERE
 Vorrat >120;
```

Shape	ID	Baumart	Vorrat	Bod
Polygon	1	Fichte	250	Brau
Polygon	2	Tanne	250	Pseu
Polygon	6	Fichte	130	Po
Polygon	5	Buche	300	Lith




```
SELECT * FROM Parzelle WHERE
  Vorrat >= (SELECT AV
 (Vorrat) FROM Parzelle);
```

Shape	ID	Baumart	Vorrat	Bod
Polygon	1	Fichte	250	Brau
Polygon	2	Tanne	250	Pseu
Polygon	5	Buche	300	Lith



1.2.2. Arithmetic operators

Arithmetic operators are used for numerical attributes. For example, there is the possibility to calculate the mean or the sum of attribute values from a series of objects. The following operators can be used as arithmetic operators: Multiplication (*), division (/), addition (+) and subtraction (#) as well as the exponent operator (exp) and modulo operator (%).

Arithmetic operators

+

-

*

/

exp

%

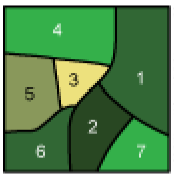
The first five operators are self#explanatory. The modulo operation gives the remainder from integer division. For example:

5 % 2 = 1

6 % 2 = 0

An example – arithmetic operators

INPUT



Graphic

Shape	ID	Baumart	Vorrat_m³/ha	Bodentyp
Polygon	1	Fichte	250	Braunerde
Polygon	2	Tanne	250	Pseudogley
Polygon	3	Kahlschlag	0	Braunerde
Polygon	4	Lärche	120	Redzina
Polygon	5	Buche	300	Lithosol
Polygon	6	Fichte	130	Podzol
Polygon	7	Lärche	100	Redzina

Table "Parcels: tree species (Baumart), stock (Vorrat), and soil type (Bodentyp)"

QUERY AND RESULT

SQL operator	Result
`SELECT Baumart, Vorrat, Bodentyp, Vorrat*2/100 as Holznutzung FROM Parzelle WHERE Vorrat > 120;`	(see result table below)

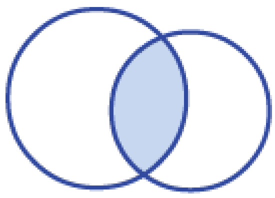
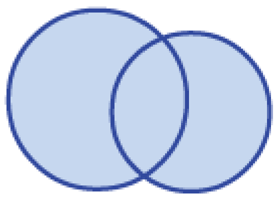
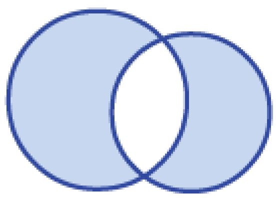
```
SELECT Baumart, Vorrat, Bodentyp,
 Vorrat*2/100 as Holznutzung
FROM Parzelle
WHERE Vorrat > 120;
```

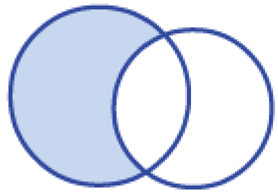
Shape	ID	Baumart	Vorrat	Bodentyp	Holznut
Polygon	1	Fichte	250	Braunerde	5
Polygon	2	Tanne	250	Pseudogley	5
Polygon	6	Fichte	130	Podzol	2.6
Polygon	5	Buche	300	Lithosol	6

1.2.3. Logical operators

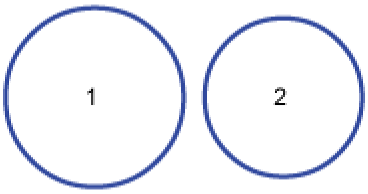
Arbitrarily complex conditions can be formulated. Thereby concatenations of the individual conditions have to be extended. Complex queries are formulated by combining different attributes.

For such queries, **logical operators** are used to combine the expressions (with two possible values "true" or "false").

Logical operators	Meaning	Result	Venn diagrams
AND	Intersection	True, if both are true.	 1 AND 2
OR	Union	True, if at least one is true.	 1 OR 2
XOR	Symmetric difference; excluding OR	True, if exactly one is true, but not both.	 1 XOR 2

NOT	Set difference (complement)	True, if one is false.	 1 NOT 2

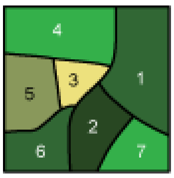
To make such queries understandable, Venn diagrams are used. Have a look at the previous table and the following explanation.
The circles number 1 and 2 graphically represent two conditions: the shaded area represents the true statement, while the part outside the circle does not correspond to a result.
To explain this situation, the above example is used.



Circle 1 : Tree species = "larch"

Circle 2 : Stock > 110 m^3/ha

Some examples
In the following, it is shown for each operator how SQL#queries are formulated and how the results are presented.
INPUT



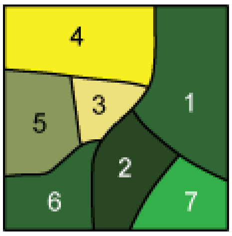
Graphic

Shape	ID	Baumart	Vorrat_m³/ha
Polygon	1	Fichte	250
Polygon	2	Tanne	250
Polygon	3	Kahlschlag	0
Polygon	4	Lärche	120
Polygon	5	Buche	300
Polygon	6	Fichte	130
Polygon	7	Lärche	100

Table

Example 1:

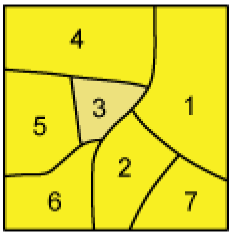
Operator	Query	SQL
AND	Find all parcels that are forested with larch and where the stock is greater than 110m^3/ha.	**select** ParzelleID, Baumart, Vorrat **from** Parzelle **where** Baumart = "Lärche"**and** Vorrat > 110



Shape	ID	Baumart	Vorrat_m³/ha
Polygon	1	Fichte	250
Polygon	2	Tanne	250
Polygon	3	Kahlschlag	0
Polygon	4	Lärche	120
Polygon	5	Buche	300
Polygon	6	Fichte	130
Polygon	7	Lärche	100

Example 2:

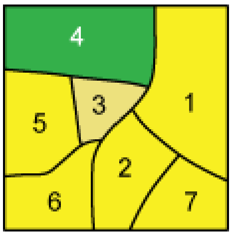
Operator	Query	SQL
OR	Find all parcels that are forested with larch or where the stock is greater than 110m^3/ha.	**select** ParzelleID, Baumart, Vorrat **from** Parzelle **where** Baumart = "Lärche" **or** Vorrat > 110

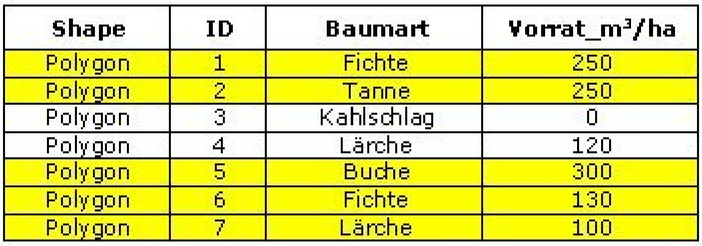


Shape	ID	Baumart	Vorrat_m³/ha
Polygon	1	Fichte	250
Polygon	2	Tanne	250
Polygon	3	Kahlschlag	0
Polygon	4	Lärche	120
Polygon	5	Buche	300
Polygon	6	Fichte	130
Polygon	7	Lärche	100

Example 3:

Operator	Query	SQL
XOR	Find all parcels that are forested with larch or where the stock is greater than 110m^3/ha, but which do not meet both of these conditions.	**select** ParzelleID, Baumart, Vorrat **from** Parzelle **where** Baumart = "Lärche" **xor** Vorrat > 110

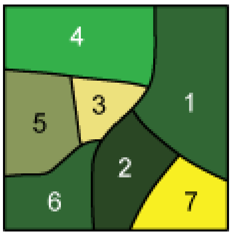


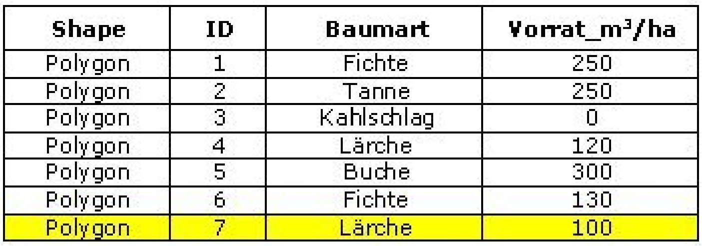


Shape	ID	Baumart	Vorrat_m^3/ha
Polygon	1	Fichte	250
Polygon	2	Tanne	250
Polygon	3	Kahlschlag	0
Polygon	4	Lärche	120
Polygon	5	Buche	300
Polygon	6	Fichte	130
Polygon	7	Lärche	100

Example 4:

Operator	**Query**	**SQL**
NOT	Find all parcels which are forested with larch but where the stock is not greater than 110m^3/ha.	**select** ParzelleID, Baumart, Vorrat **from** Parzelle **where** Baumart = "Lärche" **not** Vorrat > 110



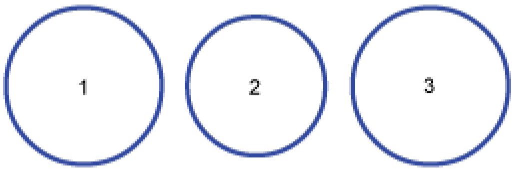


Shape	ID	Baumart	Vorrat_m^3/ha
Polygon	1	Fichte	250
Polygon	2	Tanne	250
Polygon	3	Kahlschlag	0
Polygon	4	Lärche	120
Polygon	5	Buche	300
Polygon	6	Fichte	130
Polygon	7	Lärche	100

1.2.4. Combination of operators

By combining operators, it is possible to link multiple conditions.
The Boolean operators are not commutative. That means, in complicated expressions the result depends on the mathematically defined order of the subparts of the expression. Using brackets, the order can be completely changed (Bill 1999).

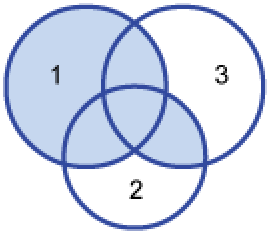
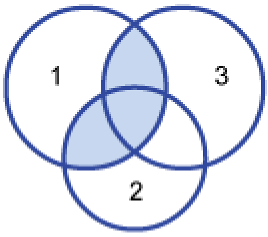
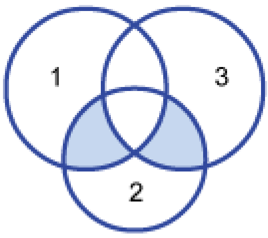
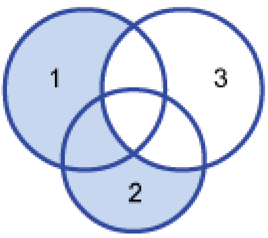
Nested Queries

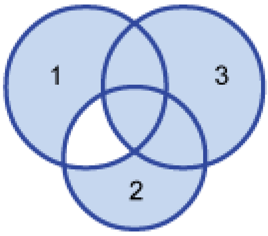


Circle 1: Tree species = "Larch"

Circle 2: Stock > 110 m^3/ha

Circle 3: Density > 80%

Venn-diagram	Condition	Corresponding SQL query
	(3 AND 2) OR 1	**Select** * **from** Parcel **where** (Density > 80% and Stock > 110 m^3/ha) or Tree species = "Larch"
	1 AND (3 OR 2)	**Select** * **from** Parcel **where** Tree species = "Larch" and (Density > 80% or Stock > 110 m^3/ha)
	(3 XOR 1) AND 2	**Select** * **from** Parcel **where** (Density > 80% xor Tree species = "Larch") and Stock > 110 ^{3}/ha
	(2 OR 1) NOT 3	**Select** * **from** Parcel **where** (Stock > 110 m^3/ha or Tree species = "Larch") not Density > 80%

	3 OR (2 XOR 1)	**Select** * **from** Parcel **where** Density > 80% or (Stock > 110 m^3/ha xor Tree species = "Larch")

Applications
Try to solve the following exercises. Consider, in particular, which operator is used:
Select all the roads of the type "Nebenstrasse", where the speed is limited to 50km/h (select the objects by clicking on the rows of the table).

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

Select all the roads (all road types), where the speed is limited to 50km/h (select the objects by clicking on the rows of the table).

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

Select all the roads, where the speed is limited to 50km/h and which are not "Nebenstrassen" that have no limited velocity of 50km/h. Select also all the roads which are "Nebenstrasse" and which have no speed limit of 50km/h (select the objects by clicking on the rows of the table).

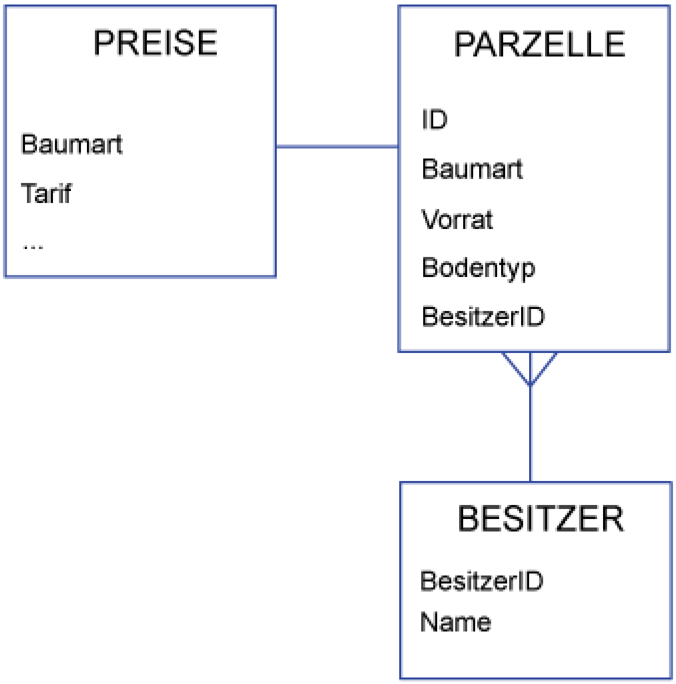
Only pictures can be viewed in this version! For Flash, animations, movies etc. see online version. Only screenshots of animations will be displayed. [link]

Select all the roads, where the speed is limited to 50km/h, but which are not "Nebenstrassen" (select the objects by clicking on the rows of the table).

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

1.2.5. Formulate queries

Formulate possible queries for the example below and try to differentiate the different query types. Publish your article in the discussion forum on WebCT.



Parzelle TABLE

Shape	ID	Baumart	Vorrat	Bodentyp	BesitzerID
Polygon	1	Fichte	250	Braunerde	1
Polygon	2	Tanne	250	Pseudogley	1
Polygon	3	Kahlschlag	0	Braunerde	2
Polygon	4	Lärche	120	Redzina	3
Polygon	5	Buche	300	Lithosol	2
Polygon	6	Fichte	130	Podzol	3
Polygon	7	Lärche	100	Redzina	3

Besitzer TABLE

BesitzerID	Name
1	Gustav Meier
2	Stephan Rohr
3	Hildegard Muster

Preis TABLE

Baumart	Tarif
Fichte	200
Tanne	180
Buche	170
Lärche	210

1.3. Geometric query

In addition to the information and search options based on theme, analysis functions based on spatial (geometric and topological) selection criteria are also implemented in GIS. In this unit, the geometric query is discussed. The geometry can be measured, such as the area or the perimeter of an object, or the distance or direction between two objects, respectively (measuring functions). To explain these concepts, it is important to distinguish between raster and vector models.

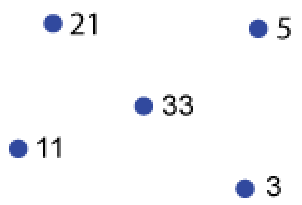
1.3.1. The geometric primitives

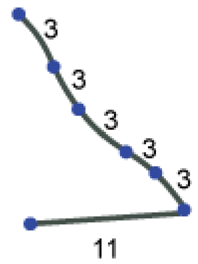
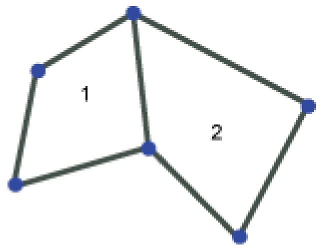
In **VECTOR MODELS**, information is assigned to points. All the other structures (lines and polygons) are based on points. The geometry of all other structures can be derived based on the coordinates of the points, such as the length of the connection line between two points, the area of a surface, and the distance between two objects (Bartelme 2000).
The three geometric primitives are arranged in 2D space, as shown in the following table.

Point
A 2D point is defined by the x# and y#coordinates.

Line
Line segments consist of one or more point pairs. Two points of a segment can be connected by a straight line or an arc. This means that lines can be made up of straight lines, curves, or a mixture of the two.

Polygon
Polygons (areas) are composed of connected lines that form a closed geometric shape. The enclosed area is the polygon.
Complex geometries can be modeled as ordered sequences of the geometric primitives.

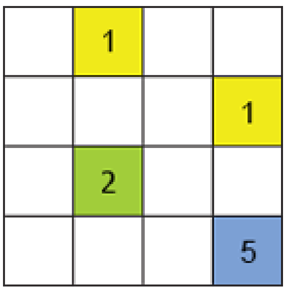
DESCRIPTION	GRAPHIC	TABLE
Point Position, no area. Defined by the coordinates.		**21** 3 5 **33** 5 4 **11** 2 3 **5** 8 4.5 **3** 7 1.5

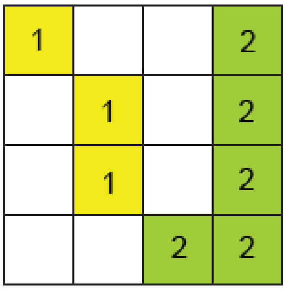
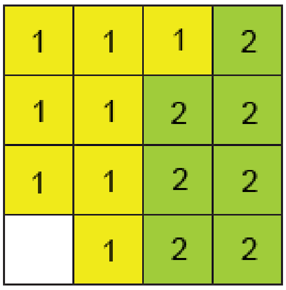
Line Length, no width. Defined by several segments, which always connect two points.		**3** 2 6 2.5 5 3 4 4 3 5 2.5 6 1.5 END **11** 2 1 6 1.5 END
Area Area and perimeter. Defined by several segments, which form a closed polygon.		**1** 1 2 2 5 5 6 6 3 END **2** 5 6 10 4 9 1 6 3 END

In **RASTER MODELS**, all values are stored in a simple array (matrix). In addition, there is a file header, which contains the following information:

- Number of rows and columns
- Cell size
- Minimum value of x# and y#coordinates

For example:
Ncols 270
Nrows 476
Xcorner 708152.60
Ycorner 121673.90
Cellsize 1
NODATA_Value -9999

DESCRIPTION	GRAPHIC	TABLE
Point One cell		<table><tr><th>Value</th><th>Count</th></tr><tr><td>1</td><td>2</td></tr><tr><td>2</td><td>1</td></tr><tr><td>5</td><td>1</td></tr></table>

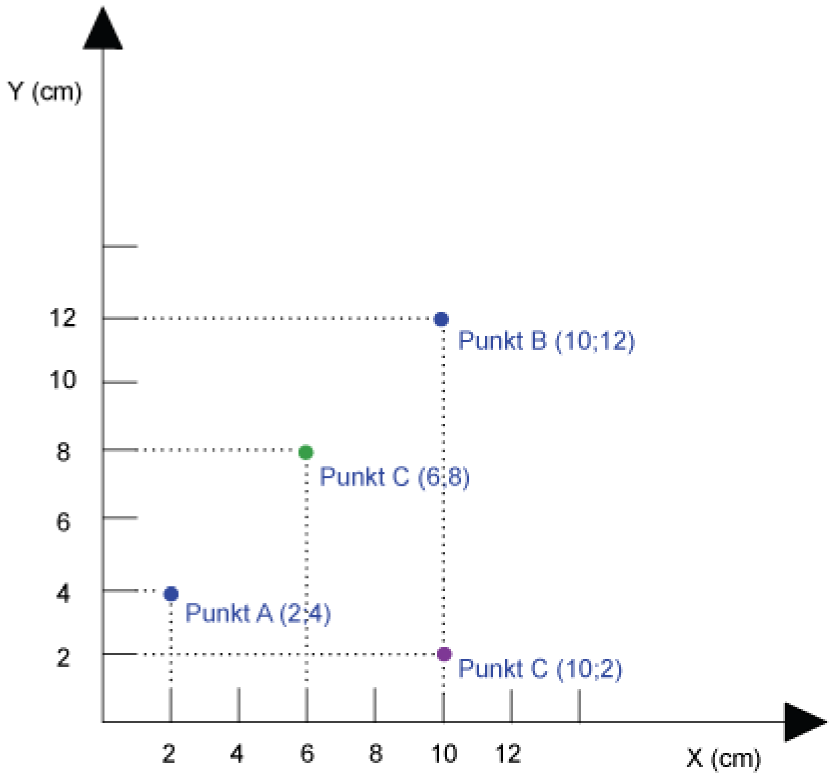
<table>
<tr>
<td>Line
Several neighboring cells in which normally one cell is connected at the edges and corners with just one or two neighboring cells.</td>
<td></td>
<td><table><tr><th>Value</th><th>Count</th></tr><tr><td>1</td><td>3</td></tr><tr><td>2</td><td>5</td></tr></table></td>
</tr>
<tr>
<td>Area
Group of neighboring cells connected at the edges and corners.</td>
<td></td>
<td><table><tr><th>Value</th><th>Count</th></tr><tr><td>1</td><td>8</td></tr><tr><td>2</td><td>7</td></tr></table></td>
</tr>
</table>

1.3.2. Geometric measurement functions

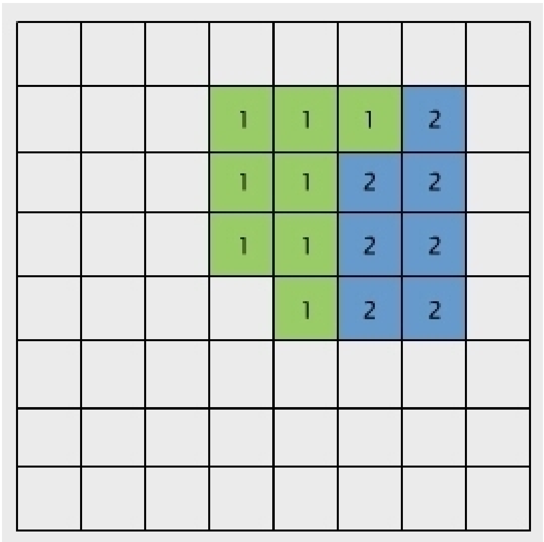
Geometry is a property of an object, just as is the thematic. With the appropriate measuring functions, queries can be performed. The general geometric queries are listed below:

Position – where (x, y)?

Vector model
Returns the position of each point from the map as x# and y#coordinates.



Raster model



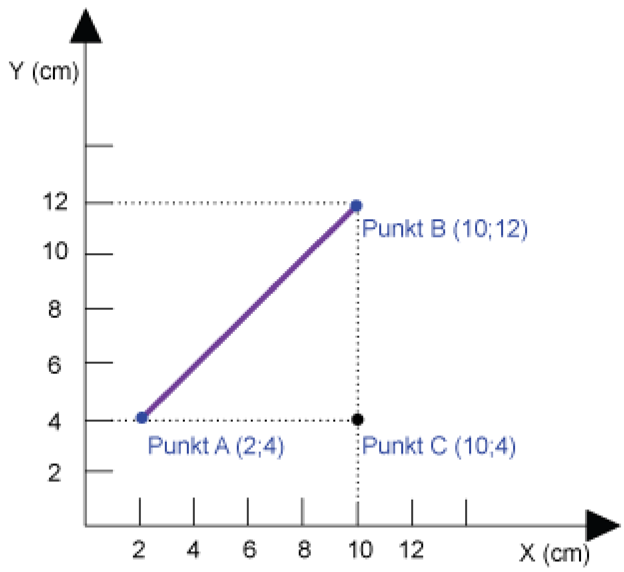
Example: Block encoding

Value	No. Cell	Location
1	8	4,2 5,2 6,2 4,3 5,3 4,4 5,4 5,5
2	7	7,2 6,3 7,3 6,4 7,4 6,5 7,5

Distance

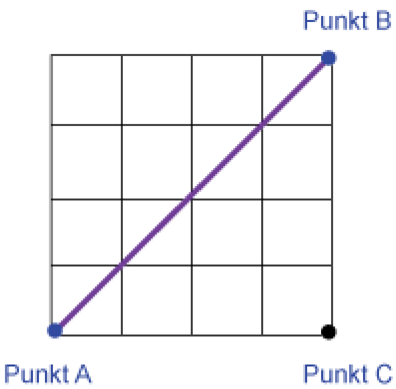
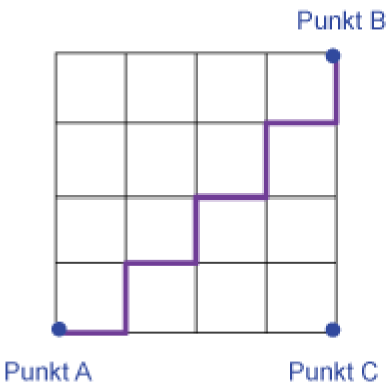
Vector model

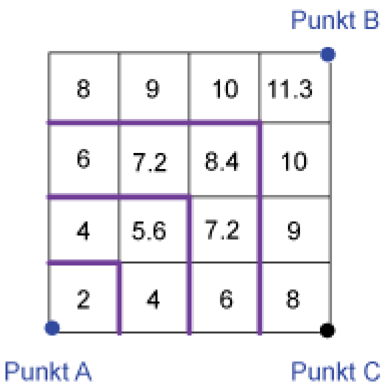
For vector data, the distance between two objects is calculated according to the Pythagorean Theorem and corresponds to the shortest distance.

 *Euclidean distance*	Distance between point A and B $AB = \sqrt{AC^2 + BC^2}$ **Example:** The distance is **11,3 cm.**

Raster model

In the raster model, there are three different approaches to measure the distance between points.

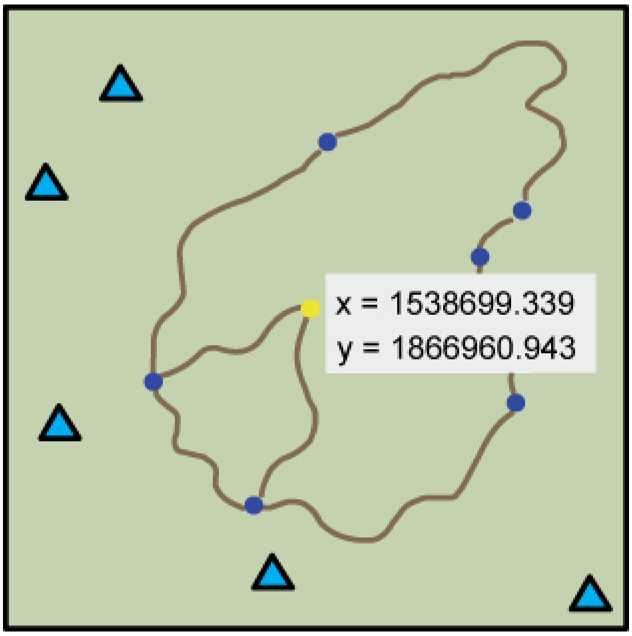
 *Euclidean distance*	Straight line between point A and point B $AB = \sqrt{AC^2 + BC^2}$ **Beispiel:** Mit einer Auflösung von 2 cm beträgt die Distanz **11,3 cm.**
 *Manhattan distance*	Distance along the cell boundary between points A and B. **Example:** Using a resolution of 2 cm, the distance is**16 cm.**

 *Neighborhood*	Concentric zones with same distance around point A. **Example:** Using a resolution of 2 cm, the distance is **11,3 cm.**

Practical examples

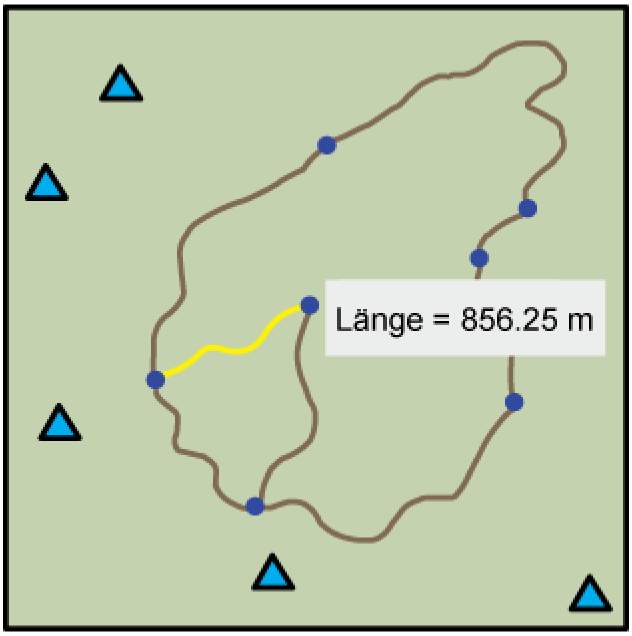
WHERE

In ArcInfo *"Measuring Where"* returns the x, y position of a selected point on a map.



LENGTH

In ArcInfo *"Length"* returns the length of a line section, which consists of two or more points.

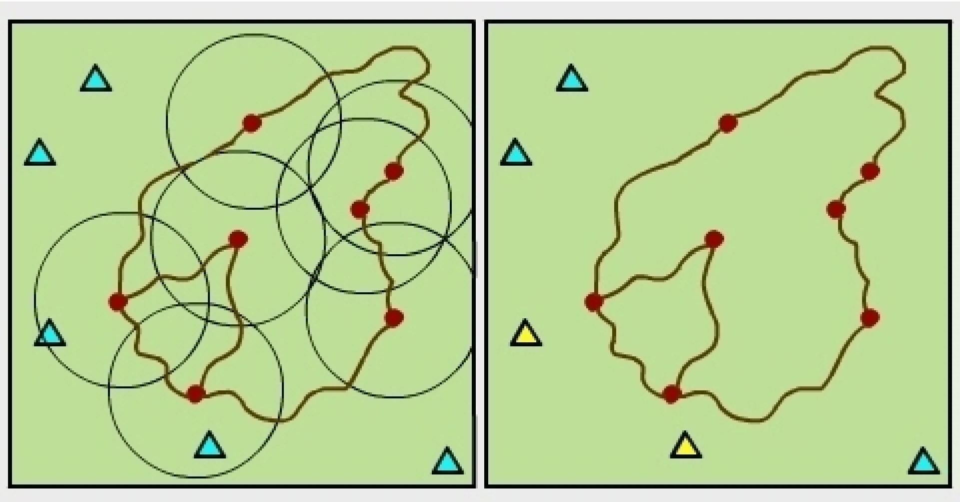


WITHIN A CERTAIN DISTANCE

Two objects are lying "within a certain distance" if the distance between them is smaller than the given distance. Traditional GIS software offer pre#programmed tools to answer these questions.

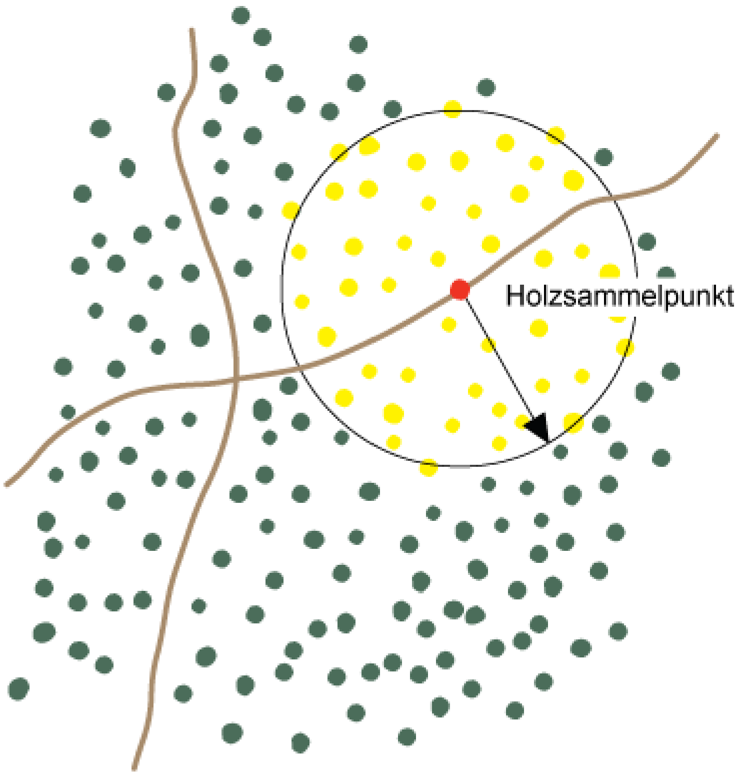
Question 1:

Select all mountain peaks that are less than 500m away from the cabins (planimetric).



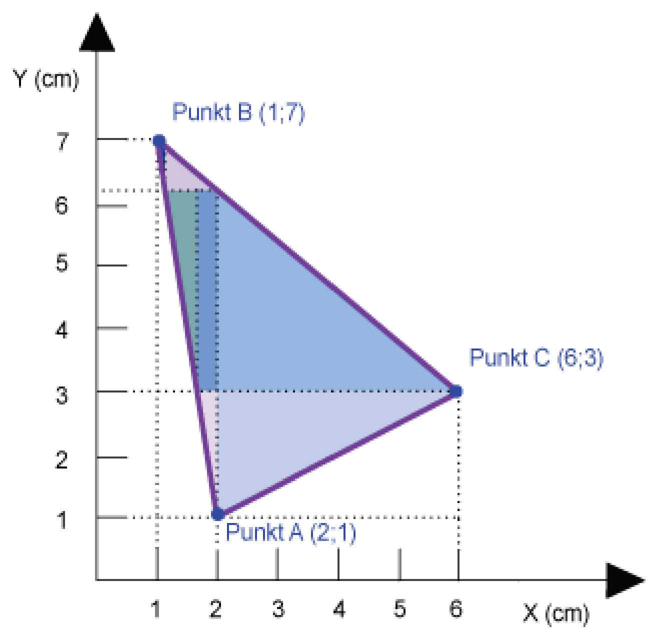
Question 2:

Select all the trees that are less than 200m away from the collection point.



Size

Vector data model



$$AB = \sqrt{1^2 + 6^2} = 6.08$$

$$AC = \sqrt{4^2 + 2^2} = 4.47$$

$$BC = \sqrt{5^2 + 4^2} = 6.4$$

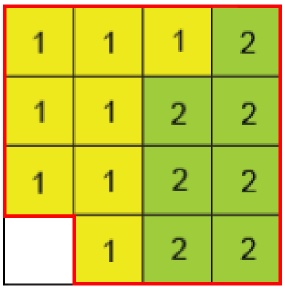
PERIMETER

Sum of the length of all single sections.

AREA

Sum of the area of the simple geometric shapes (e.g. triangles and rectangles), into which the main object can be devided.

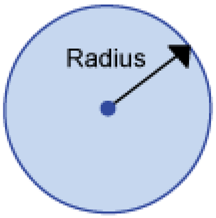
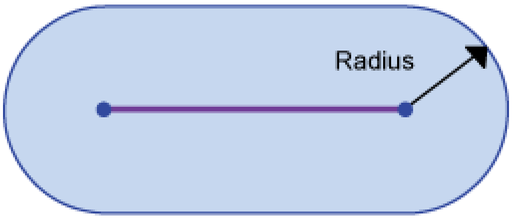
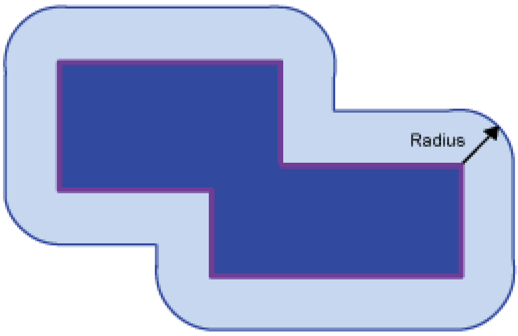
Raster data model

	**PERIMETER** Number of cell edges, which delimit the object, multiplied by the resolution of the cells. **Example:** Using a cell resolution of 2cm, the perimeter is **32 cm**. **AREA** Number of cells, which define the object, mutliplied by the area of one cell.. **Example:** Using a cell resolution of 2cm, the area is **60 cm^2.**

Proximity analysis / buffering

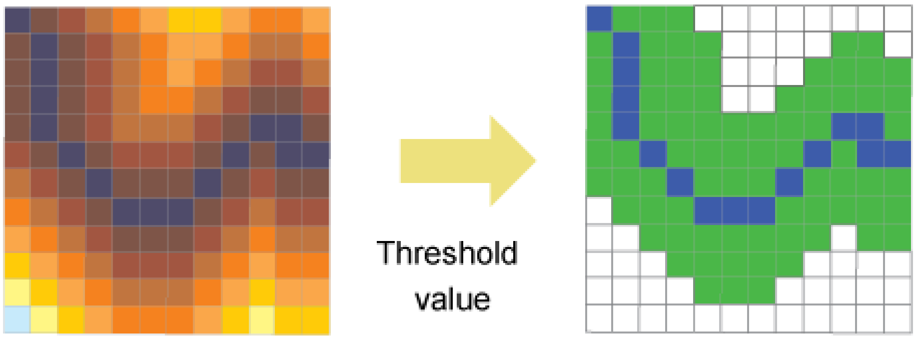
Vector data model

A buffer is a spatial expansion around points, lines and polygons defined by a distance.

	**Point buffer**
	**Line buffer**
	**Polygon buffer**

Raster data model

In the raster data model, *proximity* is calculated for the entire raster. Then a certain distance is chosen. For in-depth look have a look at the lesson **Accessibility**.



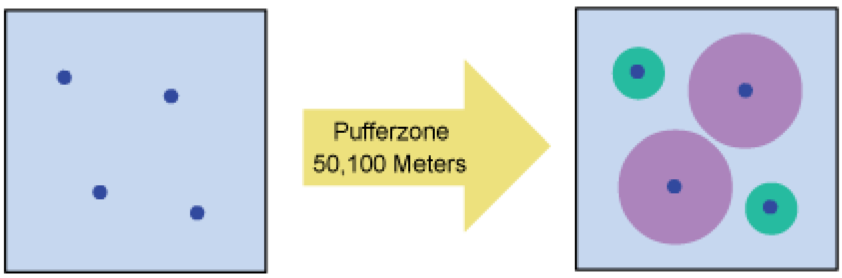
Applications

Vector data model

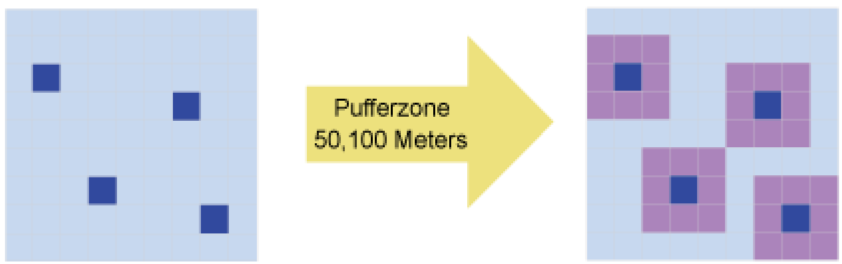
Question 1:

Canopy of trees

Vector data model



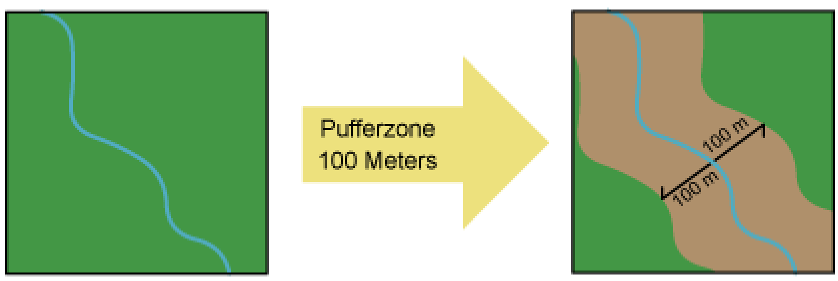
Raster data model



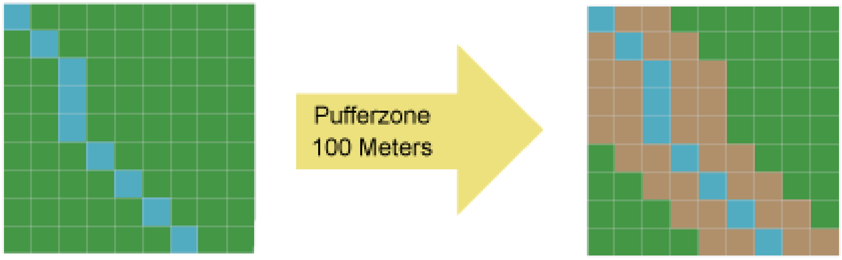
Question 2:

Calculation of the flooded area

Vector data model



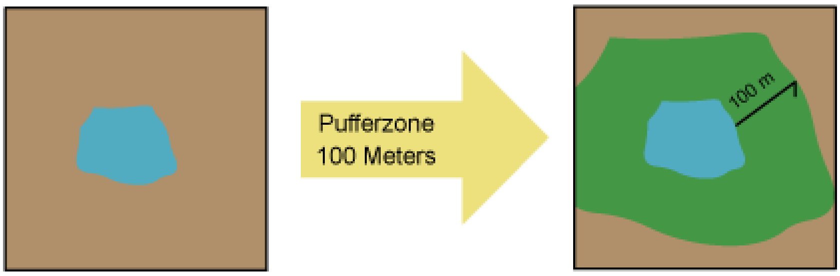
Raster data model



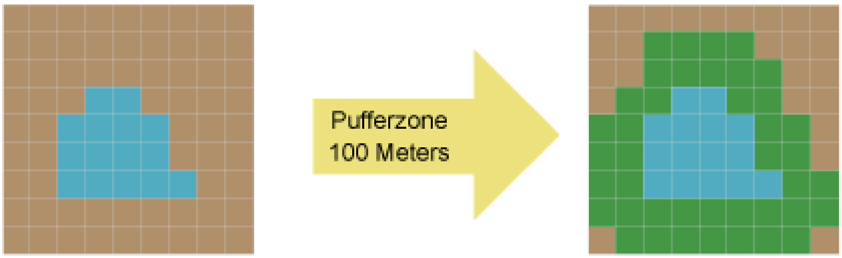
Question 3:

Flooding zone of a lake

Vector data model



Raster data model



1.4. Topological query

Standing at a crossroad, holding a situation map in the hands, it is realtively easy to determine which roads are crossing and which buildings are situated next to each other (ESRI). The implementation and further use of such functions in a GIS, however, require some knowledge.
While spatial selection criteria select objects based on their location, and while thematic queries identify elements with regards to their properties, the topological selection criteria are based on the topological arrangement of objects in space. Topological arrangements of objects are accessed through features such as "next", "part of" or "within".
In a GIS, spatial relationships are named "topology". Topological relations are made up of the geometric primitives: Point (simplest element), line (connected points), polygons (connected lines) (ESRI). Based on these structures, the system is able to identify topological relationships and perform analyses.

1.4.1. Topological relations

Topology deals with spatial and structural properties of geometric objects, independent of their extension, type, or geometric form. Among the types of topological properties of objects there are: the number of dimensions an object has or the relationships that exist between objects. All topological properties are invariant to any continuous deformation of space (Saaty 1980). The topology simplifies analysis functions, as the following examples show: joining adjacent areas with similar properties. It is important to distinguish between vector data formats and raster data formats. For example, imagine an area represented by a vector data model: it is composed of a border, which separates the interior from the exterior of the surface. The same area represented by a raster data model consists of several grid cells. There is no border existing as a separating line. Thus, the algorithms implemented for vector data models are not valid for raster data models. In the following example, we only show topological operations in vector data models.
VECTOR An interesting method for the classification of topological relations was proposed by Egenhofer (1993) (Worboys et al. 2004). It is called the 9#intersection schema. This intersection scheme is an elegant approach for the classification of topological configurations. The basic idea is based on the concept that each element is composed of a boundary (b), an interior (i), and an exterior (e). The concept of interior, boundary and complement (exterior) are defined in the general topology.

Boundary
The boundary consists of points or lines that separate the interior from the exterior. The edge of a line consists of the endpoints. The boundary of a polygon is the line that defines the perimeter.

Interior
The interior of an object consists of points, lines or areas that are in the object but do not belong boundary.

Complement
The complement, also called exterior, consists of the points, lines and areas which are not in the object.
The basic method used to compare two geometrical objects is to analyze the intersections between all the possible pairs that can be built with the interior, exterior and boundary of these two objects. Based on the resulting "intersection" matrix, the relationships between the two geometrical objects can be classified.
Two objects, A and B, are given. Both of them are represented by their interior (i), boundary (b) and exterior (e). There are nine possible relations of these two geometrical objects. They are shown in the following table.

$$ObjektA^{b} \cap ObjektB^{b} \quad ObjektA^{b} \cap ObjektB^{i} \quad ObjektA^{b} \cap ObjektB^{e}$$
$$ObjektA^{i} \cap ObjektB^{b} \quad ObjektA^{i} \cap ObjektB^{i} \quad ObjektA^{i} \cap ObjektB^{e}$$
$$ObjektA^{e} \cap ObjektB^{b} \quad ObjektA^{e} \cap ObjektB^{i} \quad ObjektA^{e} \cap ObjektB^{e}$$

The 4#intersection#matrix is sometimes used as basis for the analysis of topological relations. It is generated by omitting the components of the exterior. It is less powerful than the 9#intersectionmatrix.

$$ObjektA^{b} \cap ObjektB^{b} \quad ObjektA^{b} \cap ObjektB^{i}$$
$$ObjektA^{i} \cap ObjektB^{b} \quad ObjektA^{i} \cap ObjektB^{i}$$

The most important topological relations between objects that are used in GIS applications are listed in the following sequence. Note that there are three different geometries (point, line, polygon) on which the topological relations are applied.

Disjoint
There is no intersection area between object A and object B. Test for disjoint.

Meet
Object A and object B meet at the boundary. The boundaries meet, but not the interior. Two geometry objects meet if the boundaries touch. Test for touch.

Overlap
Object A and object B overlap. Test for intersect (inversion of disjoint).
Overlap with disjoint: The interior of an object intersects the boundary and the interior of the other object, but the boundaries do not intersect. That is the case if a line starts outside a polygon (area) and ends in the interior of the polygon.
Overlap with Intersect: The boundaries and the interior of both objects intersect. If a geometry object has to intersect another geometry object the geometry needs to be part of the dimension of the bigger object. That means:

- *Points*
  - Cannot intersect with points, lines or areas.
- *Lines*
  - Cannot intersect with points.
  - Can intersect with other lines » intersection = point.
  - Can intersect with polygons » intersection = lines (or points).

Contains
Object A contains object B. Test whether the initial geometry object encloses a different geometry object. The interior and the boundary of an object are completely inside of the other object. A geometry object cannot contain a geometry object of higher order. E.g.:

- Points can not contain lines or polygons.
- Lines can not contain polygons.

Inside

Object B lies inside object A. It is the opposite of "contain". If A is inside B, then B contains A.

Covers

Object A covers object B. The interior of an object is completely inside the other object and the boundaries intersect. A geometry object can't include a geometry object of higher dimension. That means:

- Points can not contain lines or polygons.
- Lines can not contain polygons.

Covered by

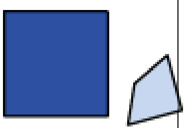
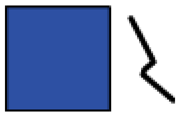
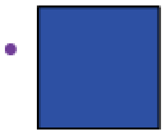
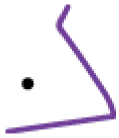
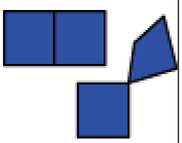
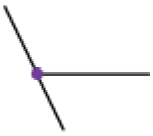
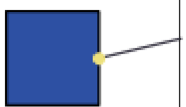
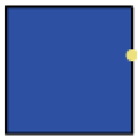
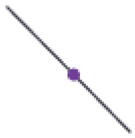
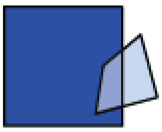
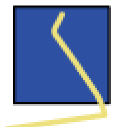
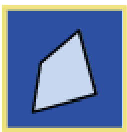
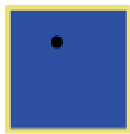
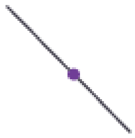
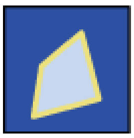
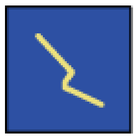
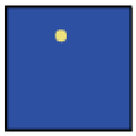
Object B is covered by object A. It is the opposite of "covers". If A is covered by B, then B covers A.

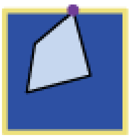
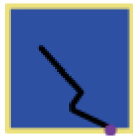
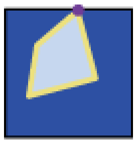
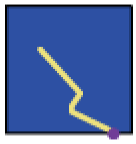
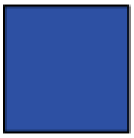
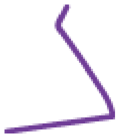
Equal

Object B and object A match. Test for equality of the initial geometry object and a different geometry object. The interior and the boundary of an object are lying on the boundary of the other object and vice versa. This happens when a line falls exactly on the boundary of a polygon. The coordinates of all components have to be equal. The compared geometry objects must be equal. That means:

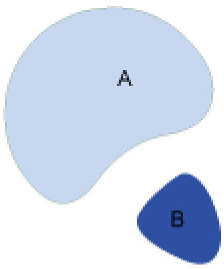
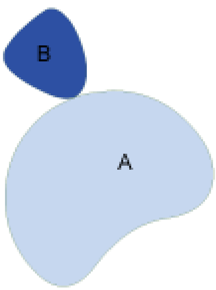
- Point = point
- Line = line
- Polygon = polygon

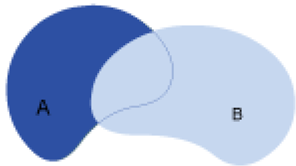
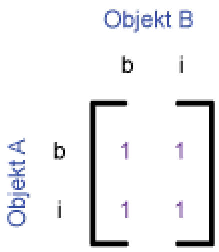
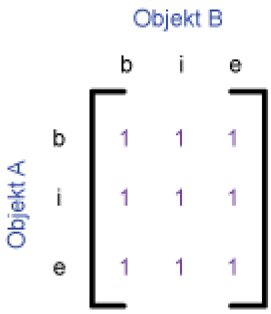
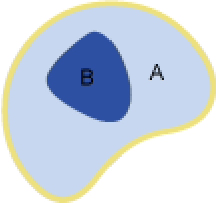
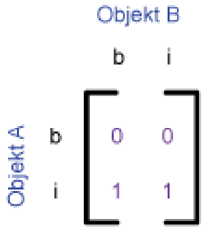
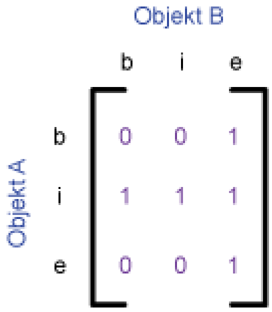
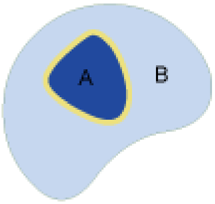
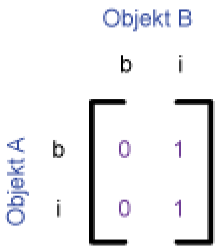
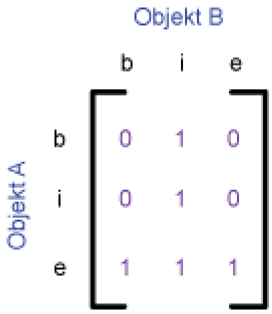
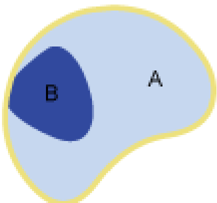
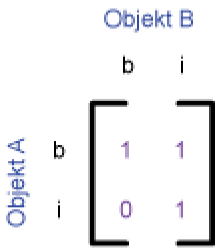
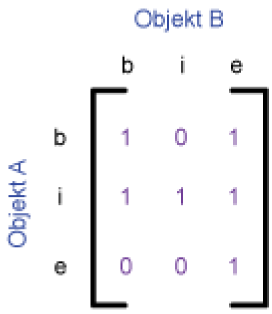
The following table shows the most common topological relations:

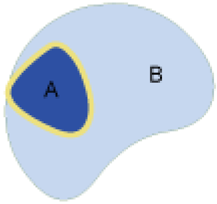
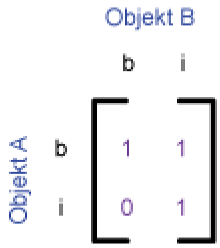
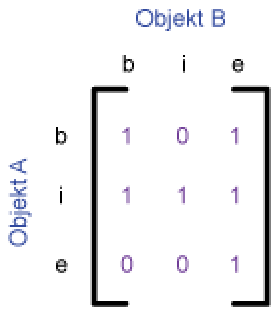
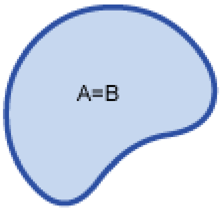
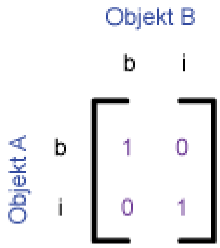
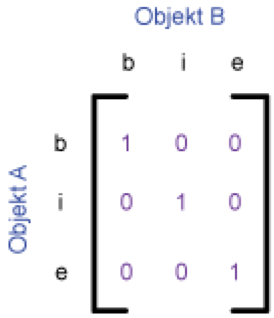
	poly-poly	line-line	point-point	poly-line	poly-point	line-point
Disjoint						
Meet						
Overlap						
Contains						
Inside						

Covers						
Covered by						
Equal						

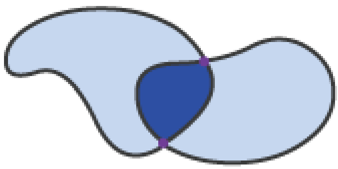
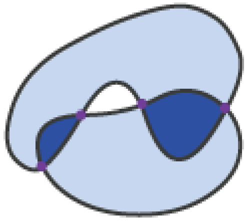
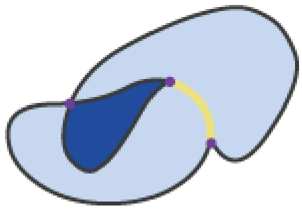
The following table shows the 9#intersetion#schema and the 4#intersection#schema for some typical topological relations between two polygons, proposed by Egenhofer et al. (1993). The relations are given by the values 0 and 1. Every pair has an empty (0) or an occupied (1) intersection.

Topological relation	Graphical description	4-intersection-matrix	9-intersection-matrix
Disjoint		Objekt B: b i; Objekt A: b i $\begin{bmatrix}0 & 0\\0 & 0\end{bmatrix}$	Objekt B: b i e; Objekt A: b i e $\begin{bmatrix}0 & 0 & 1\\0 & 0 & 1\\1 & 1 & 1\end{bmatrix}$
Meet		Objekt B: b i; Objekt A: b i $\begin{bmatrix}1 & 0\\0 & 0\end{bmatrix}$	Objekt B: b i e; Objekt A: b i e $\begin{bmatrix}1 & 0 & 1\\0 & 0 & 1\\1 & 1 & 1\end{bmatrix}$

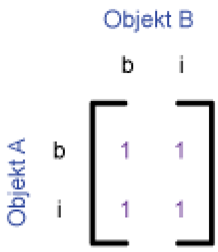
Overlap			
Contains			
Inside			
Covers			

Covered by			
Equal			

There is at least one disadvantage in this model: there is no possibility to conceptually separate different situations.

These three situations presented correspond to the following matrix:



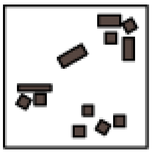
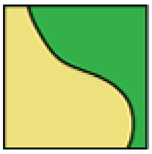
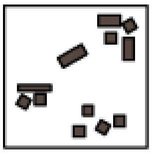
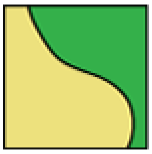
1.4.2. Topological operators

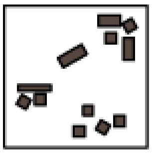
Topological operators are components of spatial analysis functions of a GIS. These functions are fundamental and therefore implemented in commercial GIS, such as ArcGIS, Geomedia or MapInfo. Each system has its own formulations of spatial queries; some of them allow the user to perform topological queries using SQL. Spatial databases, such as Oracle, have been and continue to be, developed for data management purposes in

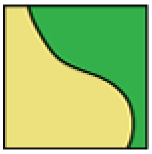
GIS. Further topological operators, which are adapted to the corresponding data structure, are developed. In the following list some of the functions and the corresponding operators, provided by Geomedia, Oracle Spatial and ArcView, are shown.

TOPOLOGICAL RELATION	ORACLE	GEOMEDIA	ARCVIEW
Disjoint	disjoint	-	are within a distance of
Meet	touch	meet	-
Overlap	overlap by intersect	overlap	intersect
Contains	contains	entirely contains	completely contains
Inside	covers	are entirely contained by	contains the center of
Covers	inside	contain	have their center in
Covered by	coveredby	are contained by	are completely within
Equal	equal	are spatially equal	-

Relationships between polygons and other objects are the most frequent. Below are some examples of topological queries:

LAYERS		INPUT	QUERY	RESULTS	
N.1	**N. 2**			**Table**	**Graphically**
			Find the buildings, which lie completely within the forest.	Shape | ID | AREA Polygon | 1 | 105 Polygon | 2 | 50 Polygon | 3 | 50 Polygon | 4 | 110 Polygon | 5 | 110 Polygon | 6 | 115 Polygon | 7 | 50 Polygon | 8 | 50 Polygon | 9 | 50 Polygon | 10 | 50 Polygon | 11 | 50 Polygon | 12 | 50	
			Find the buildings, which intersect the boundary of the forest.	Shape | ID | AREA Polygon | 1 | 105 Polygon | 2 | 50 Polygon | 3 | 50 Polygon | 4 | 110 Polygon | 5 | 110 Polygon | 6 | 115 Polygon | 7 | 50 Polygon | 8 | 50 Polygon | 9 | 50 Polygon | 10 | 50 Polygon | 11 | 50 Polygon | 12 | 50	





Find the buildings, whose centroid lies within the forest.

Shape	ID	AREA
Polygon	1	105
Polygon	2	50
Polygon	3	50
Polygon	4	110
Polygon	5	110
Polygon	6	115
Polygon	7	50
Polygon	8	50
Polygon	9	50
Polygon	10	50
Polygon	11	50
Polygon	12	50

Application

As described earlier, topological queries refer to the reciprocal locations of objects in space. The following examples illustrate this concept.

Select the huts that are reached first from the starting point (green point).

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

SHAPE	ID	NAME
Point	1	Sillerenbühl
Point	2	Gilbachegge
Point	3	Gilbach
Point	4	Bergläger

Select the huts that are in the forest (dark green area).

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

SHAPE	ID	NAME
Point	1	Sillerenbühl
Point	2	Gilbachegge
Point	3	Gilbach
Point	4	Bergläger

Select the areas that touch the forest (dark green area).

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

SHAPE	ID	OBJECTVALUE
Polygon	1	Geröll in Wald
Polygon	2	Steinbruch
Polygon	3	Feld
Polygon	4	Feld
Polygon	5	Steinbruch
Polygon	6	Feld
Polygon	7	Geröll in Wald
Polygon	8	Wald
Polygon	9	Steinbruch
Polygon	10	Wald
Polygon	11	Feld
Polygon	12	Geröll in Wald
Polygon	13	Geröll in Wald
Polygon	14	Steinbruch
Polygon	15	Feld
Polygon	16	Feld
Polygon	17	Steinbruch
Polygon	18	Geröll in Wald
Polygon	19	Feld

Which parcels are crossed by the river Allenbach?

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

SHAPE	ID	OBJECTVALUE
Polygon	1	Geröll in Wald
Polygon	2	Steinbruch
Polygon	3	Feld
Polygon	4	Feld
Polygon	5	Steinbruch
Polygon	6	Feld
Polygon	7	Geröll in Wald
Polygon	8	Wald
Polygon	9	Steinbruch
Polygon	10	Wald
Polygon	11	Feld
Polygon	12	Geröll in Wald
Polygon	13	Geröll in Wald
Polygon	14	Steinbruch
Polygon	15	Feld
Polygon	16	Feld
Polygon	17	Steinbruch
Polygon	18	Geröll in Wald
Polygon	19	Feld

1.5. Summary

An information system is a question#response system based on a data set. Such systems contain tools for the computational analysis of information. If the stored data have a spatial reference, the system is called geographic information system (GIS). It allows the interrogation and display of attribute values based on spatial criteria and vice versa. Hence the term data analysis, that includes all those analysis, queries, evaluations etc. that can be performed on structured and stored geodata. Queries can be performed according to different approaches: thematic, geometric and topological. Geometry is expressed by the spatial reference, which is assigned to all objects. They fulfill the requirement of location and extension. The topological properties are expressed by the relations of neighborhood, containment, and overlapping etc. Besides geometric characteristics that exist for spatial data, there are also thematic properties. Those properties are stored in tables. A query can be classified in two ways, depending on the result. In a direct query, there is a subset extracted from the database and the original data are not modified by this process. In a manipulation, new space related information elements are generated, which can be used in further analysis operations. The results of data processing and data manipulation in GIS should be represented in a form which is understandable for the user, or in a form which enables data sharing.

1.6. Glossary

Abfrage:

Die Abfrage ermittelt räumliche Beziehungen zwischen Elementen eines oder mehrerer Themen, um auf dieser Basis eine Lokalisierung von Objekten zu erreichen. Die Analyseergebnisse können dann bei konkreten Fragestellungen zur Entscheidungsfindung beitragen.

Konsistent:

Gewährleisten der Widerspruchsfreiheit innerhalb einer Datenbank; d. h., dass der Inhalt einer Datenbank alle vordefinierten Konsistenzbedingungen ("Constraints") erfüllt.

Operators:

In search algorithms, operators enable the logical conjunction of search items using keywords like AND, OR, and NOT.

SQL:

"Acronym for Structured Query Language. A syntax for retrieving and manipulating data from a relational database. SQL has become an industry standard query language in most relational database management systems" (ESRI), e.g. Oracle, DB2, Access, etc.

Topologie:

Die Topologie beschäftigt sich mit den räumlichen und strukturellen Eigenschaften der geometrischen Objekte unabhängig von ihrer Ausdehnung und ihrer Form. Die topologischen Eigenschaften äussern sich in Beziehung der Nachbarschaft, des Enthaltenseins, der Überschneidung und Ähnlichem. (Carosio 2000)

1.7. Bibliography

- **Bartelme, N.**, 2000. *Geoinformatik – Modelle, Strukturen, Funktionen*. 3rd. Berlin: Springer.
- **Bill, R.**, 1999. *Grundlagen der Geo-Informationssysteme*. Karlsruhe: Wichmann Verlag.
- **Carosio, A.**, 2000. *Geoinformationssysteme – Band 1*. Institut für Geodäsie und Photogrammetrie, ETH Zürich.
- **Egenhofer, M.J.**, 1993. A model for detailed binary topological relationships. *Geomatica*, Vol. 47, no. 3-4, 261-273.
- **ESRI**. *ArcInfo Help*.
  Download: http://www.esri.com
- **ESRI**. *GIS Dictionary: SQL* [online]. Available from: http://support.esri.com/en/knowledgebase/Gisdictionary/browse [Accessed 02.05.2016].
- **Longley, P.A.; Goodchild, M.F.; Maguire, D.J.; Rhind D.W.**, 1999. *Geographical Information Systems. Principles, techniques, applications and management*. New York, etc.: John Wiley & Sons.
- **Saaty, T.L.**, 1980. *The Analytic Hierarchy Process: Planning Setting Priorities, Resource Allocation*. New York: McGraw-Hill International.
- **Worboys, M., Duckham, M.**, 2004. *GIS. A Computing Perspective. Chapter 4. Models of geospatial information*. Boca Raton, etc.: CRC Press.