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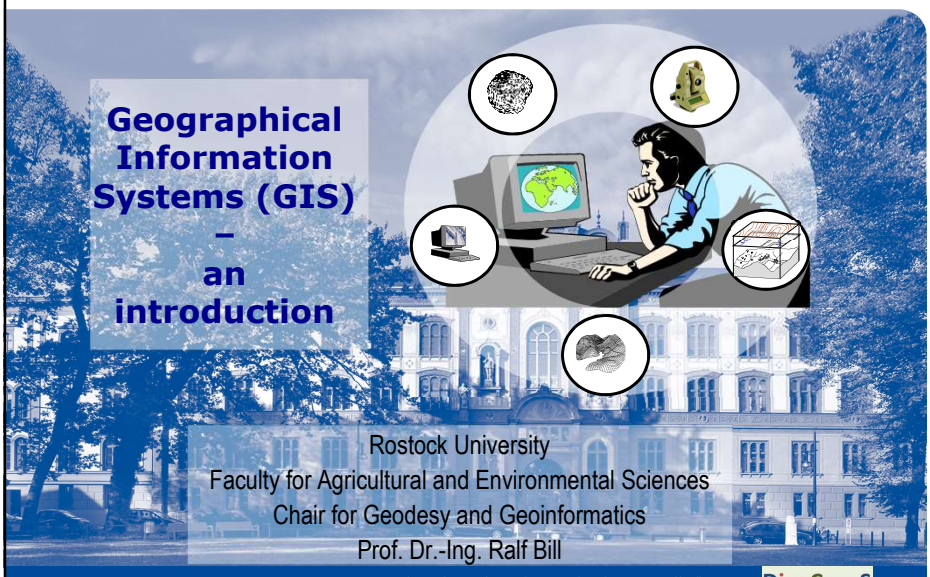

Geographical Information Systems (GIS) – an introduction

Rostock University
Faculty for Agricultural and Environmental Sciences
Chair for Geodesy and Geoinformatics
Prof. Dr.-Ing. Ralf Bill

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Lecturer
Prof. Dr.-Ing. Ralf Bill

- 1972-1979: studied Geodesy at University for Applied Sciences Mainz and the Technical Universities in Berlin and Karlsruhe.
- 1982: Dr.-Ing. TU Karlsruhe.
- 1979-1985: Research assistant TU Karlsruhe.
- 1985-1989: GIS development engineer Wild, Heerbrugg (CH).
- 1989-1994: Leader of the research group on GIS Stuttgart University .
- Since 1994: Professorship in Geodesy and Geoinformatics Rostock University.
- Since 1999: Leader STZ Geoinformatik Rostock

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Goal of the lectures and exercises

- Lectures
  - introduce state-of-the-art and recent developments in GIS
  - illustrate applications of GIS
  - provide a foundation for own studies and application activities in agro-biodiversity
- Exercises
  - develop skills for own GIS research and application
  - give a short introduction in practical usage of QGIS software
  - help to understand UN SDGs

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Content

- Introduction
  - Basic terms/definitions
- State of research and development
- Methods
  - Spatial referencing - coordinates
  - Data, data types and the Geo-object
  - Dimensions
  - IMAP – the processing chain in a GIS
  - Products and standards
- Applications
  - From LIS, EIS, NIS, .. to ..IS
  - Agriculture, Forestry etc.
- Research
- Take home message
- Literature

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INTRODUCTION

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❖ BASIC TERMS / DEFINITIONS

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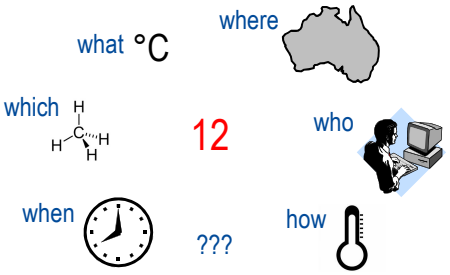
Information = data + context



- **Data** in the classical sense of computer science are simply signs, which are stored, compared, processed and written by a computer.
- **Information** is purpose-related knowledge resulting from rules and knowledge of those being familiar with the data in order to be able to create facts and interpretable results in a given context.

Reference: Bill, 2016

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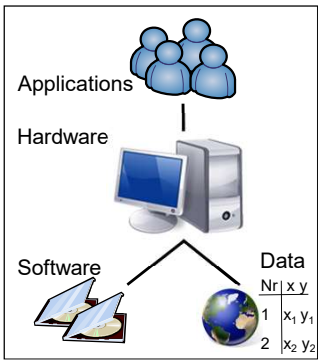
System

- In the sense of **abstract system theory**, a **system** stands for an articulated whole that is closed off from its environment by a shell (**system boundary**) and has a certain relationship to it.
- A system usually breaks down into **individual elements**, which under certain circumstances can also be related to each other, but which themselves can in turn be regarded as systems (subsystems).
- In computer science a **system** is a combination of **hardware** und **software**, combined in such a way that they can be regarded as a unit being feasible to solve specific **applications** based on relevant **data**.



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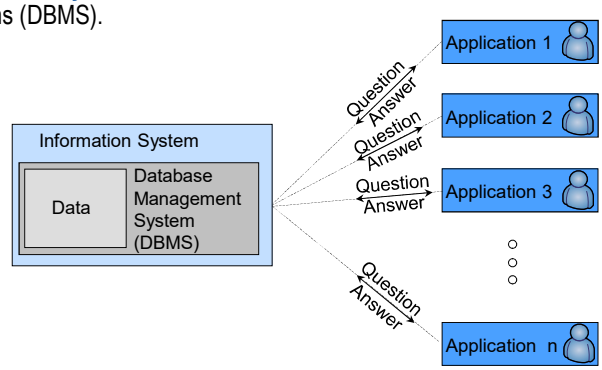
Information systems

- A **system** is a set of elements that are interrelated.
- **Information systems** are general tools to manage and analyse data.
- **Information systems** are based on databases and their database management systems (DBMS).



- An **information system** is basically a "question / answer" system for a set of data.

Reference: Bill, 2016

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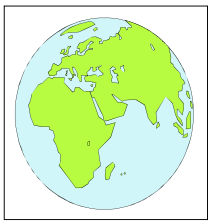
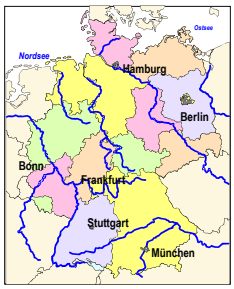
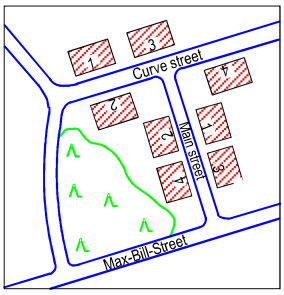
'Geo' – the magic linking element



a) global



b) regional



c) local (horizontal)

ge|o..., Ge|o...,
(greek. gẽ, gaĩa) "Earth"

- All information in a GIS is somehow related to the Earth or parts of it.

⇨ It is spatially referenced.

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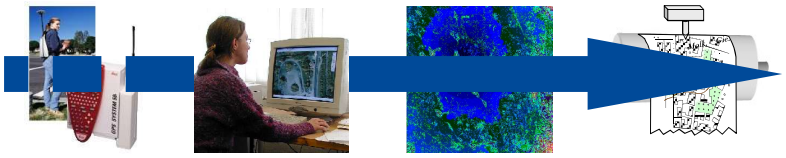
Definition Geographical Information System (GIS) I

GIS is a **computer-based system** to

- **I**nput,
- **M**anage,
- **A**nalyse and
- **P**resent

spatial information.

I	Hardware
M	Software
A	Data
P	User



I **M** **A** **P**

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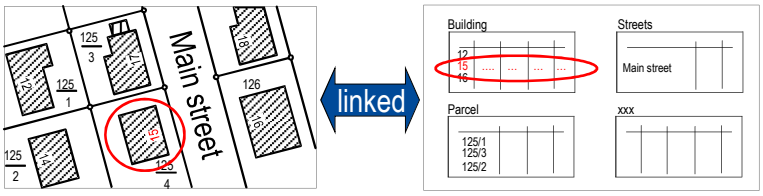
Definition GIS II Map + DB in the computer

- Map = (carto-)graphic data
- Database = attributes, describing data



- Feature (or object)-oriented modeling
  - Feature: *Agricultural field plot*
  - *Feature ID*
  - Geometry: *Perimeter polygon (x_1,y_1,.. x_n,y_n)*
  - Topology: *Area, neighbours*
  - Attributes: *Owner, current crops, area size ..*
  - Graphical representation: light yellow

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Geoinformatics
Spatial Information Science

- "Geoinformatics (or Spatial Informatics, Spatial Information Science) is dedicated to the **development and application of methods and concepts of computer science to space-related problems**.
- The common core element of geoinformatics is the **spatial reference**.
- Geoinformatics deals with the **nature, function and provision of geoinformation and its applications**.
- The knowledge gained in this way is incorporated into the technology of **geographical information systems** (GIS)."

Source: Definition 1.8 in R. Bill (2016), Page 17 (translated);
www.geoinformatik.uni-rostock.de, N. Bartelme (2005), N. de Lange (2006)

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STATE OF RESEARCH AND DEVELOPMENT

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GIS: State-of-the-art

- **GIS technology**
  - developments benefit from general IT
    - Internet and World Wide Web
    - Hardware /Software development (Client/Server, DBMS, mobile components ..)
  - based on standards (ISO), specifications (OGC) and legal regulations
  - uses OGC Web Services such as WMS, WFS etc.
  - relies on national Spatial Data Infrastructures (SDI)

⇨ **Acceptable hardware/software for ubiquitous GIS applications**

- **Geodata and GIS products**
  - Wide range of geodata available on the market worldwide
  - fosters Open Data
  - GIS product variety on the market
  - fosters Open Source
  - Interoperability for data, services and products
  - …

⇨ **Efficient product and data portfolio**

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GIS: State-of-the-art

- **Applications**
  - GIS is used for a huge variety of spatial problems
  - GIS replaces analogue maps in many fields => digitalisation
  - Classical domains such as cadaster, topography, environment, utilities
  - The public is using GIS
  - ….

⇨ **GIS is integrated in day-by-day workflows**

- **Research topics**
  - New data capture methods (e.g. geosensor networks/Internet-of-things)
  - Mobile usage
  - Spatio-temporal analysis methods (e.g. Big data, spatial data mining)
  - Public usage (e.g. social media, location as a service)
  - Real-time applications
  - …

⇨ **Still a lot of challening research topics for the future**

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Methods

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❖ SPATIAL REFERENCING

COORDINATES

http://media.merchantcircle.com/23841905/world-globe_full.jpeg

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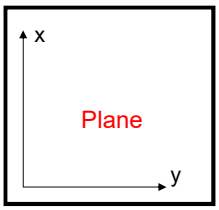
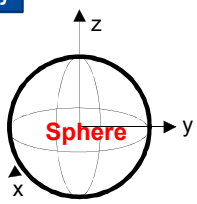
The Earth – a complex figure and its approximations

- **Mathematical description**

x,y{,z}

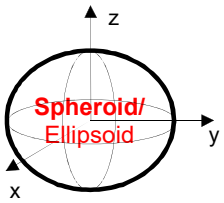


Eratosthenes

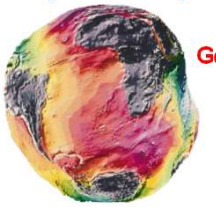


Newton

- **Physical description**



Gauß
Listing



Geoid

z

Potential (x,y,z) in Earth gravity field is constant

Source: GFZ Potsdam, Germany

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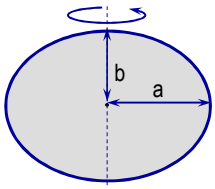
Reference ellipsoids as earth's substitutes

- Mathematical geometrical substitute figures for the earth, created by rotating an ellipse around its axis, being defined by its semi-minor and semi-major half axis.
- 3 types of spheroids/ellipsoids:
  - conventional defined ellipsoids (arc measurements)
  - regional best-fitting ellipsoids (astro-geodetic system)
  - global ellipsoids (mean earth surface approximation, geocentric equipotential ellipsoid)



Ellipsoid	Year	semi-major axis a [m]	semi-minor axis b [m]
Bessel (Germany)	1841	6.377.397	6.356.079
Clarke (GB)	1866	6.378.206	6.356.584
Hayford (USA)	1924	6.378.388	6.356.912
Krassowskij (Russia)	1942	6.378.245	6.356.863
GRS 80/WGS 84	1980	6.378.137	6.356.752

Reference: Resnik/Bill 2018

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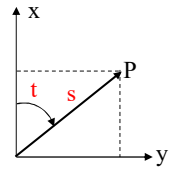
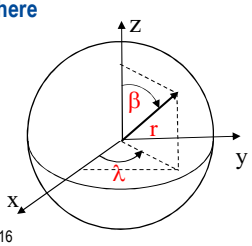
Coordinate System (CS) in 2D or 3D

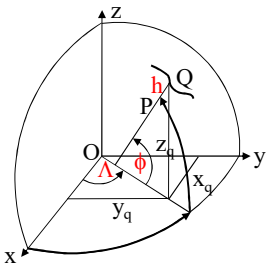
- Polar coordinates versus cartesian coordinates
  - Plane



  - Sphere



- Ellipsoidal polar coordinates versus ellipsoidal cartesian coordinates
  - Ellipsoid



Reference: Bill, 2016

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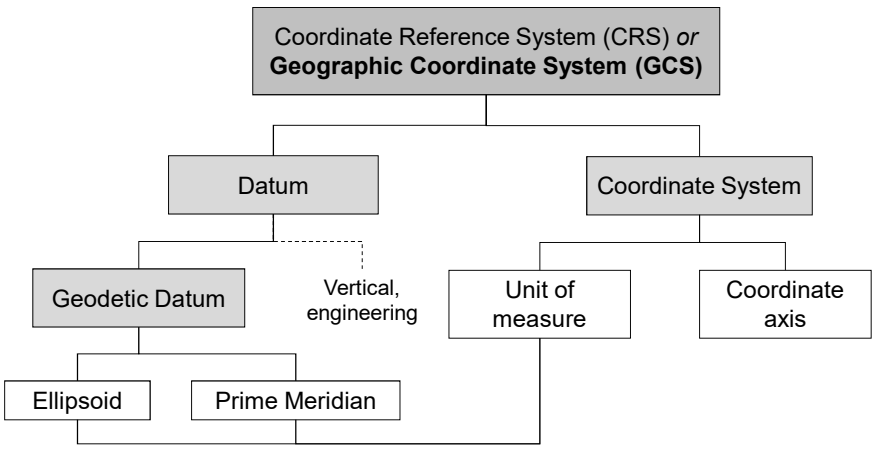
Coordinate reference system (CRS)

- Often named "Geographical coordinate system (GCS)"



Reference: Bill, 2016, ISO19111:2002 Geographic Information—Spatial Referencing by Coordinates

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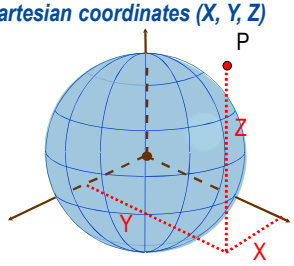
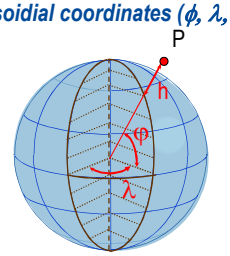
World Geodetic System 1984 (WGS 84)

- Global reference system in the form of a **geodetic coordinate reference system**.
- Coordinate system with **metric coordinate specifications**.
- **Geodetic datum** is defined by a **global ellipsoid** (also named WGS'84).
- The **orientation of the coordinate axes** is defined so that:
  - the **x-axis** of the cartesian system **passes through the Greenwich prime meridian**,
  - the **xy-plane** is **placed in the equatorial plane**,
  - the **z-axis coincides** with the **central axis of the earth rotation**.

Cartesian coordinates (X, Y, Z)



Ellipsoidial coordinates (ϕ, λ, h)



WGS 84 is used by GNSS worldwide !

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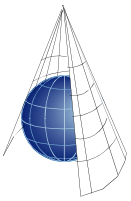
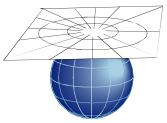
Projections of the earth's surface on a plane

- A **map projection** is used to portray all or part of the curved earth on a flat surface. This cannot be done without some distortion. Every projection has its own set of advantages and disadvantages. There is no "best" projection. **"no flat map can be both: length equivalent and conformal."**
- Selection of **reference figures**





Conical projection:
- formed by considering a **cone** tangential to the ellipsoid.
- Lambert projection as an example.

Cylindrical projection:
- special case of the conical projection: cone becomes a **cylinder.**
- Universal Transverse Mercator (UTM) projection as the most widely used of all projections.

Azimuthal projection:
- special case of the conical projection, cone degenerates to a **plane**
- Stereographic projection is an example.

Reference: Resnik/Bill 2018

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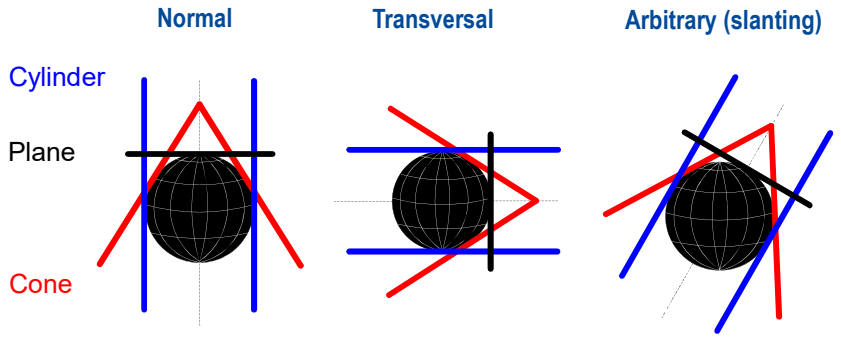
Projections of the earth's surface on a plane

- Selection of the **orientation of the reference figures**



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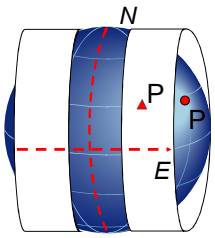
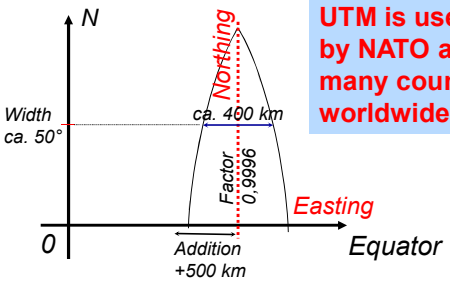
Universal Transversal Mercator (UTM) Projection

- Transversal cylinder projection





UTM is used by NATO and many countries worldwide !

- Coordinate conversion

	Geographical coordinates		UTM Coordinates (WGS 84)	
Point	Longitude (° ' ")	Latitude (° ' ")	Easting (m)	Northing (m)
Aachen	6 05 03	50 46 33	32 294 431	5 628 951
Rostock	12 05 57	54 04 18	33 310 204	5 995 387
Oldenburg	8 13 03	53 09 36	32 447 681	5 890 355

https://www.engineeringtoolbox.com/utm-latitude-longitude-d_1370.html

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UTM Properties Example: Germany

Criteria	Universal Transversal Mercator (UTM)
a. Related to the earth figure	GRS80/ETRS89-Ellipsoid
b. Projected on ..	Cylinder
c. Reference mapping figure	Cutting cylinder
d. Orientation	Transversal
e. Stripe width	Each 6° a new cylinder
f. Stripe numbers	60 cylinders in total around the earth
g. Projection properties	True to length at the cutting meridian, in total conformal
h. Zones in Germany	Zone 32, 33
i. Northing counted from	Equator
j. Easting formed by	Reference number [°] = Zone, Mean meridian 500000m

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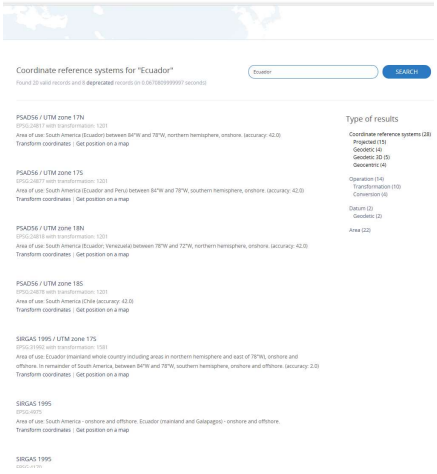
Coordinate Reference Systems Example: Ecuador

- To get an overview which CRS is used in a country use the **EPSG Geodetic Parameter Dataset**, a structured dataset of Coordinate Reference Systems and Coordinate Transformations
- European Petroleum Survey Group (EPSG)
- Now: Surveying and Positioning Committee of the International Association of Oil & Gas Producers

- EPSG database (https://epsg.io/)



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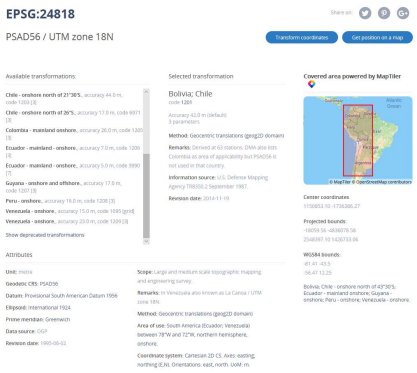
Coordinate Reference Systems
Example Ecuador

```
PROJCS["PSAD56 / UTM zone 18N",
    GEOGCS["PSAD56",
        DATUM["Provisional_South_American_Datum_1956",
            SPHEROID["International 1924",6378388,297,
                AUTHORITY["EPSG","7022"]],
            TOWGS84[-288,175,-376,0,0,0,0],
            AUTHORITY["EPSG","6248"]],
        PRIMEM["Greenwich",0,
            AUTHORITY["EPSG","8901"]],
        UNIT["degree",0.0174532925199433,
            AUTHORITY["EPSG","9122"]],
        AUTHORITY["EPSG","4248"]],
    PROJECTION["Transverse_Mercator"],
    PARAMETER["latitude_of_origin",0],
    PARAMETER["central_meridian",-75],
    PARAMETER["scale_factor",0.9996],
    PARAMETER["false_easting",500000],
    PARAMETER["false_northing",0],
    UNIT["metre",1,
        AUTHORITY["EPSG","9001"]],
    AXIS["Easting",EAST],
    AXIS["Northing",NORTH],
    AUTHORITY["EPSG","24818"]]
```



Each component has an EPSG code !

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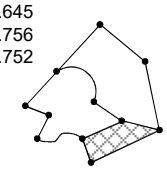
Primary metric:
direct spatial reference (CRS)

- **ISO 19111: 2019 Geographic information — Referencing by coordinates (formerly ISO 19111:2007)**
- Features described by coordinates or construction rules
  - Properties:
    - \+ defined metrics
    - \+ defined reference system
    - \+ high accuracy expected
    - – multidimensional search criteria

Coordinates

x	y	z
64695.740	23685.123	123.768
64623.546	23626.876	125.645
64593.341	23653.265	122.756
64695.740	23685.123	121.752

x	y
64695.740	23685.123
64623.546	23626.876
64593.341	23653.265
64695.740	23685.123



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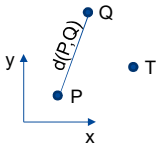
Metric - mathematics for coordinates

- Definition:
  - A metric on a set X is a **mapping d: X*X on R_0** with the following **properties** for any P, Q, T from X
    - **Idempotence:** **d(P,Q) = 0 if P=Q**
    - **Symmetry:** **d(P,Q) = d(Q,P)**
    - **Triangle inequality:** **d(P,Q) <= d(P,T) + d(T,Q)**
  - A pair (X,d) means **metric space**.



- Common distance functions:
  - Vector data: **Euclidean distance:** $d_E = sqrt((x_i-x_j)*(x_i-x_j)+(y_i-y_j)*(y_i-y_j))$
  - Raster data with: $d_1=|i-k|$ $d_2=|j-l|$ mit P(i,j) und Q(k,l)
    - **City Block distance:** $d_4 = d_1+d_2$
    - **Chessboard distance:** $d_8 = max(d_1,d_2)$
    - Euclidean distance: $d_E = sqrt (d_1*d_1+d_2*d_2)$

N.4

Neighbourhood type

N.8

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Secondary metric: indirect spatial reference

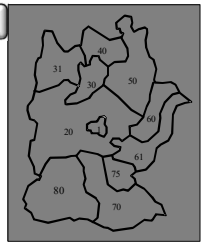
- **ISO 19112:2019 Geographic information — Spatial referencing by geographic identifiers (formerly ISO 19112:2003)**
- Features described by some kind of identifiers
  - Properties:
    - \+ 1-dimensional search criteria
    - \- weakly-defined metric
    - \- indirect reference system
    - \- low, variable accuracy
- Examples

Addresses

Telephone book

Glock Manfred Isegrimweg 25	244 72 10
Glock Udo Filderweg 29	659 10 25
Glocke Eckhard Heuweg 9a	493 27 11
Glockenbring G. Schellberg 7	264 54 55
Glocker H. Einsteinstr. 29	62 66 23

Code numbers



Site names

Ecuador
Quito
Rostock
Andes

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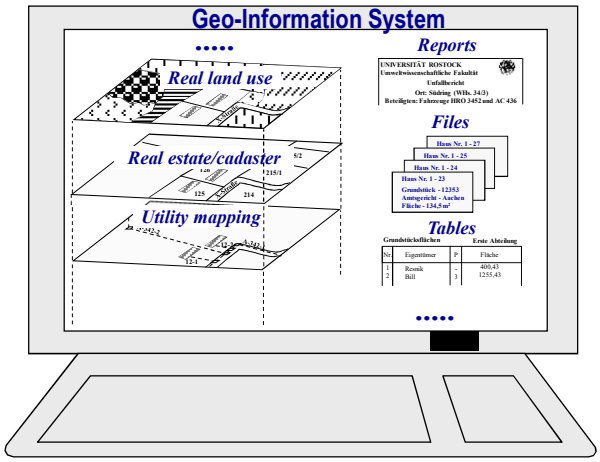
Spatial references – the important link

- Around 80% of all branch-specific administrative, logistic, and strategic activities in an enterprise, governmental organisation and our daily life have a spatial reference.



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❖ DATA, DATA TYPES AND THE GEO-OBJECT

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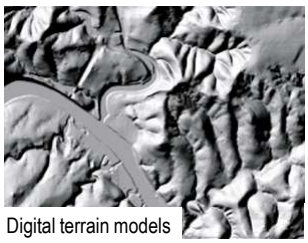
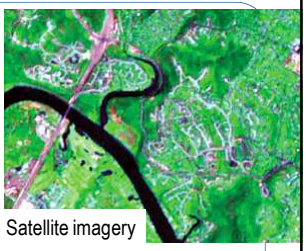
Data in a GIS

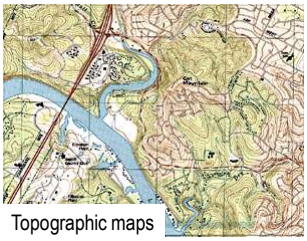
Contour lines



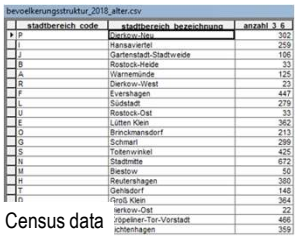
Digital terrain models



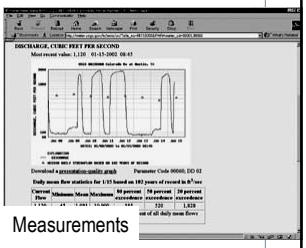
Satellite imagery



Topographic maps



Census data



Measurements

Source: http://erg.usgs.gov/isb/pubs/gis_poster/

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Data types in GIS: Geometrical data

- Geometrical elements are points, lines and polygons in vector form, pixels in raster form.
- They are defined in a coordinate reference system and describe the shape and position of objects.
- They may occur in analogue and/or digital, vector and/or raster form.
- Coordinates carry the geometric information.
- **Mathematical basis:** Computational geometry

Element	Vector		Raster	
	Digital	Analogue	Digital	Analogue
Point	x,y-coord.		Pixels	
Line	x,y-coord.-sequence		Pixels	
Polygon	closed x y coord.-sequence		Pixels	

Properties :

Vector data
- according to object lines
- logical structure
- well-known methods of acquisition
- small amount of data

Raster data
- according to position
- limited logical structure
- simple data acquisition
- large amount of data

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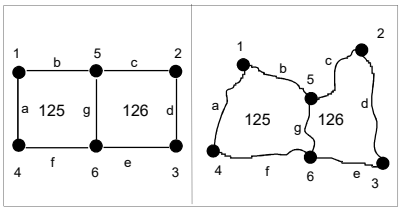
Data types in GIS: Topological data

- Topological elements are nodes (0-cells), edges (1-cells) and meshes (2-cells).
- Describe geometry without coordinates (so-called neighbourhood relations) and are invariant towards topologic transformations.
- The edge carries the topological information.
- **Mathematical basis:** Topology, Graph theory

Geometrically not equal
.. but ..
Topologically equal !



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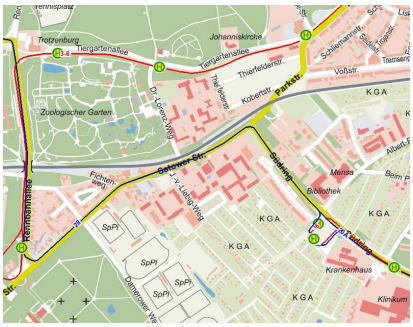
Geometry versus topology

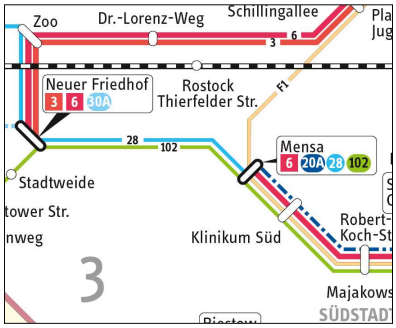
- Geometry



- a city map is a geometrical representation

⇨ One can measure distances and directions in it!!

- Topology



- a public traffic schema plan is a topological representation

⇨ One can find connections/relations in it!!

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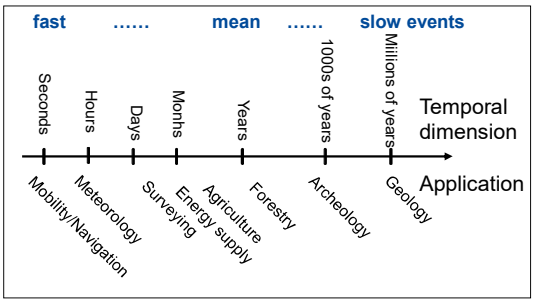
Data types in GIS: Time and dynamics

- defines temporal reference system.
- Feature as an event within a certain interval.
- Feature has a time stamp.
- **Mathematical basis:** Time series analysis



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Data types in GIS: Attributes, semantics

- Attributes, descriptive data, special data.
- Name all non-geometric elements such as text, numbers, measurements etc.
- Are captured in a special context to solve special problems.
- Occur in analogue form as well as digital.
- **Mathematical basis:** Set theory, Relational algebra.

Analogue	Digital
Protocols	Data bases
Registers	Information systems
Notes	Files
..	..

Point number	Street name	Parcel number	Grey values
128	A-street	128/1	64=field 64,126,32=forest

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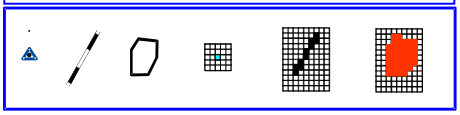
Data types in GIS: Graphical descriptions

- Graphic data = geometry data + graphical descriptions (styles)
- Graphical descriptions such as symbols, hatching, grey scales, line sizes, polygon fill etc.
- **Basis:** Cartography, Visualisation

Object repres.	Attribute-type	Fill type	Line type	Symbol type		
Attribute type:	Font	Height	Width	Orient.	Distanc.	Direction
Fill type:	Pattern	Border line	Area fill	Scale		
Line type:	Type	Repeating symbols	Parallel Lines	Color	Scale	
Symbol type:	Primitives	Masking	Origin	Scale		



- are found in analogue form (e.g. map) and digital form (e.g. screen graphic).
- usually have additional text elements in order to match standard graphic elements.

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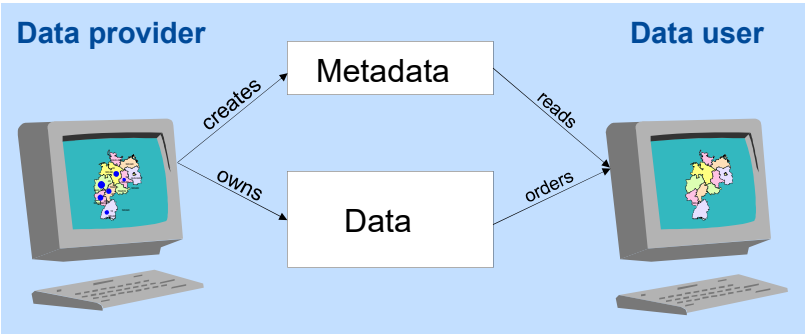
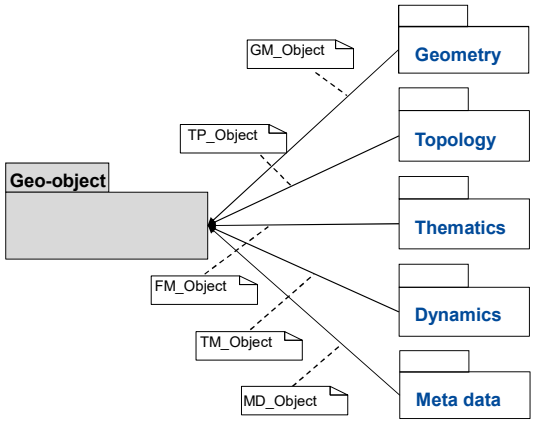
Metadata

- **ISO 19115:2003 Geographic information — Metadata**
- Metadata is information used to describe information, i.e. information that is necessary to make the data usable in an information system.
- Who offers what and how much, about what, how, in what context and at which conditions?



Geo-object / spatial feature

- has
  - geometrical properties
  - topological properties
  - thematical properties
  - temporal properties
- is described by meta information.
- has an object identifier (key).
- belongs to a feature/object class.



Discrete or continuous geo-objects

- Discrete phenomena: Features with well-defined borders and spatial extent
  - z.B. Building, parcel, street, agricultural field plot.

⇨ **Vector data**

- Continuous phenomena varying in space and in most cases not sharply defined
  - e.g. soil types, temperature distributions or terrain surfaces.
- **Fields (Coverages)** may be described:
  - discrete:
    - using triangles or grid cells (**=> Raster data**)
    - or **Tesselations** (such as Thiessen-Polygonen)
  - continuous:
    - using the form of functions (e.g. interpolation functions), connecting spatial positions with attribute values, e.g. trend surfaces.

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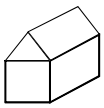
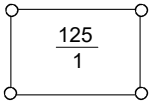
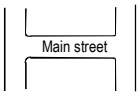
Basic object classes and spatial references



Buildings
Coordinates
Street, House No.
Real Estate No.

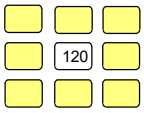


Parcels
Coordinates
Street, House no.
Real Estate No.



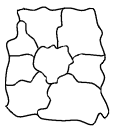
Streets
Coordinates
Street Name
Address

....



Building Blocks
Coordinates
Street Names
Block No.

Quarters
Coordinates
Name
Postal code



City
Coordinates
Name
Postal code

....

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An example for modeling: Geo-object „Building"

- **Data modeling: Building**

Building { ObjectID

+ Geometry (coordinates of the perimeter in 2 D)

+ Topology (is of type mesh in 2 D, has neighbouring buildings)

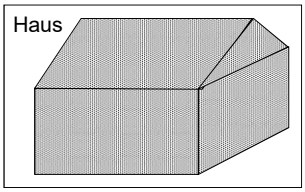
+ Thematics (has owner, number of floors, usage, value)

+ Dynamics (year of construction)

+ Metadata (created by, at datum, ..)

+ belongs to **Class „Buildings"**

}



- **Visualisation modeling: Building**

Building {

has graphical description (black broderline with two-dimensional hatching)
for visualisation in a thematic large scale map

}

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❖ DIMENSIONS

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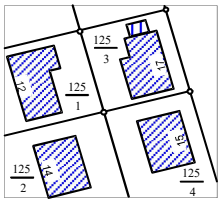
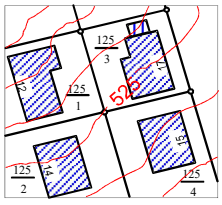
Geometrical dimension

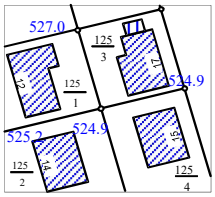
2D - Planimetry



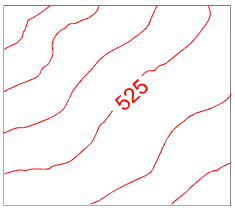
2D+1D - Planimetry + DTM
(no link between position and height)



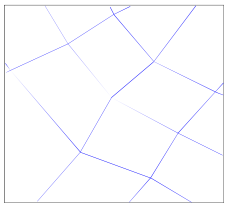
2.5D - x,y,z



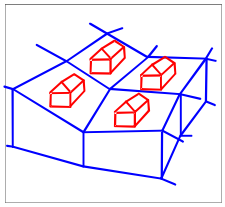
3D-Line model
(Planimetry+ link to DTM)



3D-facet model



3D-Volume model



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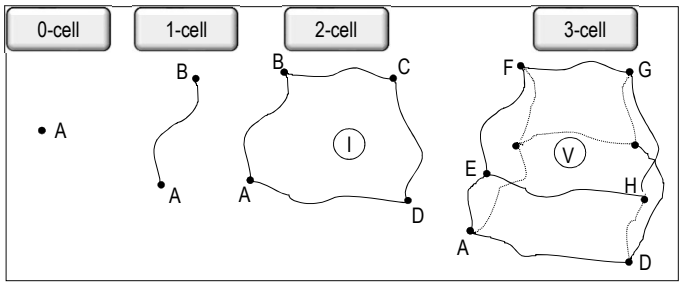
Topological dimension

- Nodes (0-dimensional)
- Edges (1-dimensional)
- Meshes (2-dimensional)
- Solids (3-dimensional)



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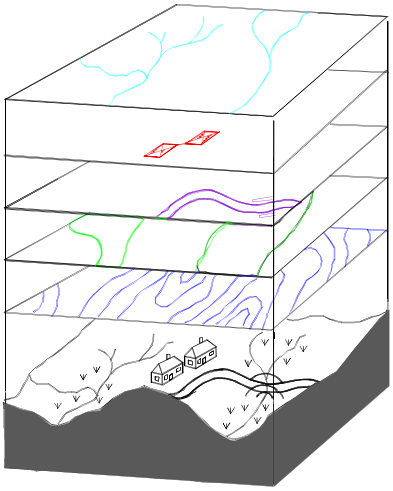
Thematical dimension



Natural waters

Settlement areas

Traffic

Land usage

Rain fall

Dimension N=5

Real world

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Temporal dimension

- 1-dimensional (1D-time, t)
- Combination with space results in 4-dimensional space-time (4D-time, (x; y; z; t))
- In applications we differenciate between:
  - **2D+time (x; y; t)**
  - **2,5D+time (x; y; z = f(x,y); t)**
  - **3D+time = 4D (x; y; z; t)**

Time axis
Time line

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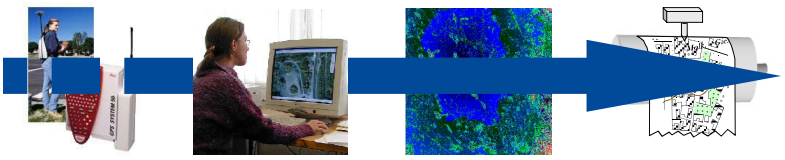

I M A P

❖ IMAP – THE PROCESSING CHAIN IN A GIS

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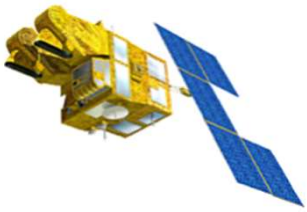
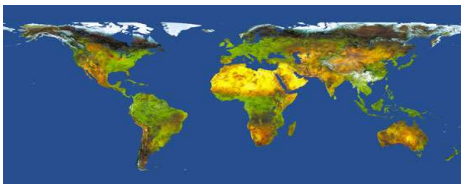
Input / capture of information in GIS

- Getting the data/information into the system by:
  - Geodetic methods
  - Photogrammetric methods
  - Remote sensing
  - Digitising/scanning
  - Attribute data collection
  - Integrating existing digital information
  - … and
- defining their spatial reference system.





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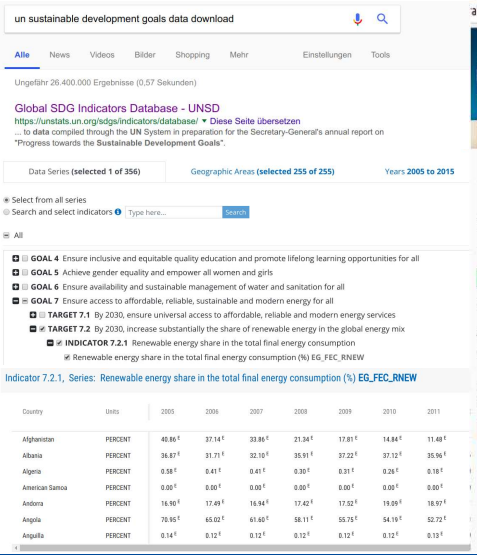
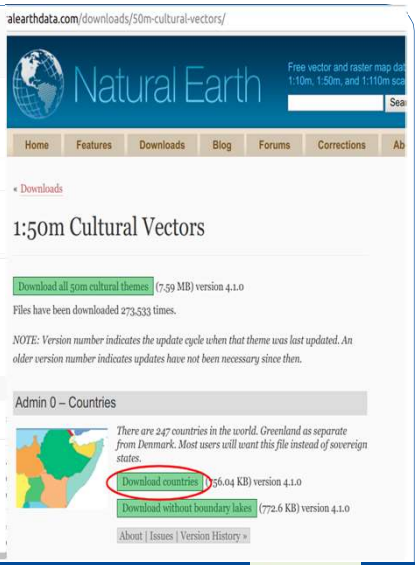
Example SDG: Existing digital information





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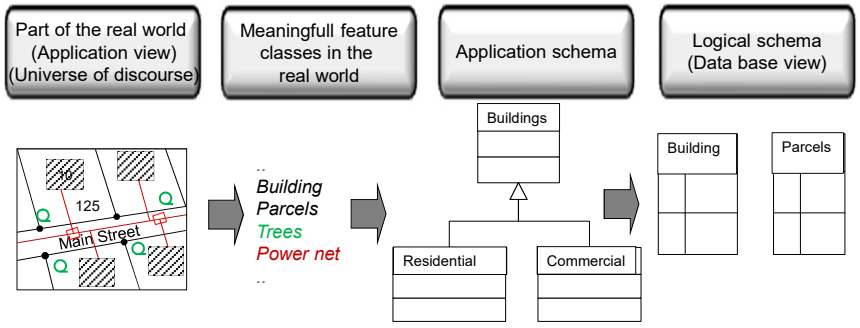
Management/Modeling of information in GIS

- Data models
  - Modeling languages
  - Relational data models
  - Object-oriented modelling
- Data management
  - Data bases/information systems
  - Relational/object-relational DBs

Modeling at different levels: From an application oriented view to the database view



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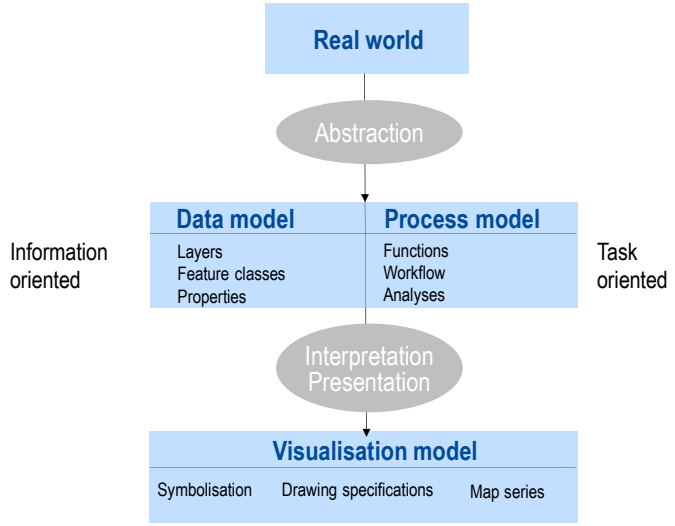
From real world to digital models in the computer



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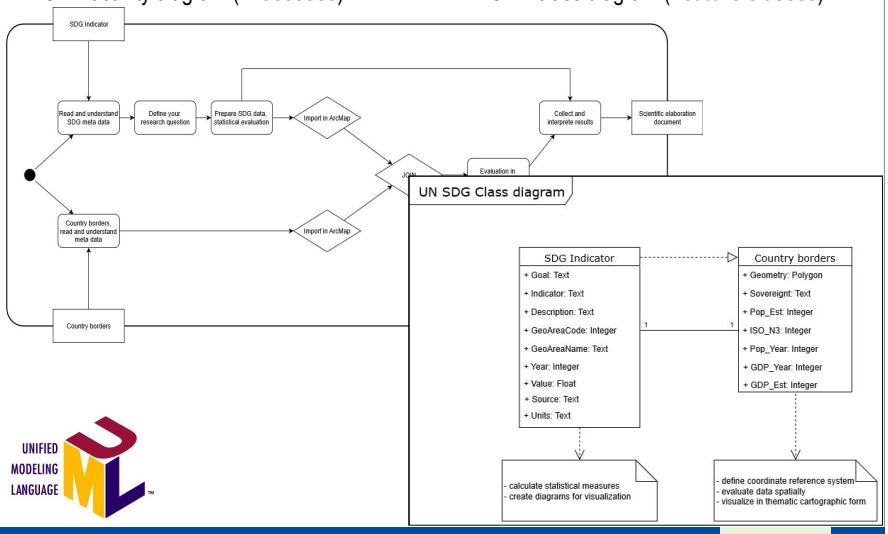
SDG: Modeling the real world

- UML activity diagram (**Processes**)
- UML class diagram (**Feature classes**)



UNIFIED MODELING LANGUAGE

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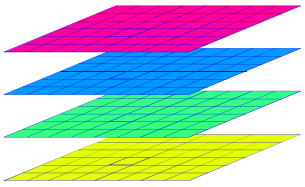
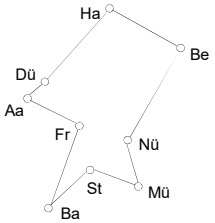
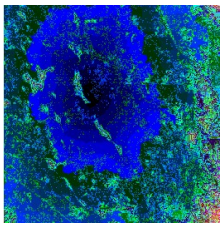
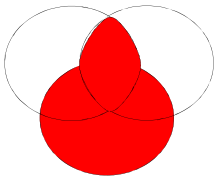
Analysis of information in GIS

- Geometrical methods
- Topological methods
- Temporal methods
- Statistical methods
- Set methods
- Models and simulation









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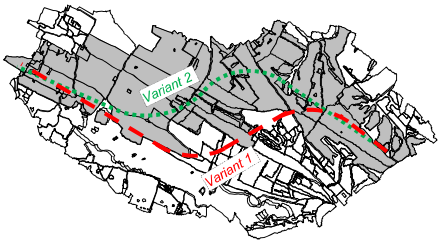
Basic problem of spatial analysis

- Given a user-defined task and an information system with **data on different phenomenon A, B, C, ...**
- **Establish function(s)** through which the available data may be involved and manipulated to provide the required output (e.g. presentations such as maps, graphs, reports, …) related to the problem

Link: U = f (A, B, C ...)

- Functions f
  - Selection/Boolean operations
  - Algebraic terms
  - Reclassification
  - Polygon overlay
  - …



Overlay with biotope map	Variant 1	Variant 2
Biotope value per m²	0,13	0,57
Compensation amount (Biotope in m²)	225,486	240,159

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5 questions a GIS can answer!

1. **Location:** What is at a given location?
   - to find out what exists at a particular location (place name, zip code or address).
2. **Condition:** Where does something occur?
   - use spatial analysis to find a location where certain conditions are satisfied (e.g., an unforested section of land at least 2,000 square meters in size, within 100 meters of a road, and with soils suitable for supporting buildings).
3. **Trends:** What has changed since ...?
   - combination of the first two to find the differences within an area over time.
4. **Patterns:** What spatial patterns exist?
   - May determine whether cancer is a major cause of death among residents near a nuclear power station. Just as important, you might want to know how many anomalies there are that do not fit the pattern and where they are located.
5. **Modeling/Simulation:** What if ...?
   - to determine what happens, for example, if a new road is added to a network. Answering this type of question requires geographic as well as other information.

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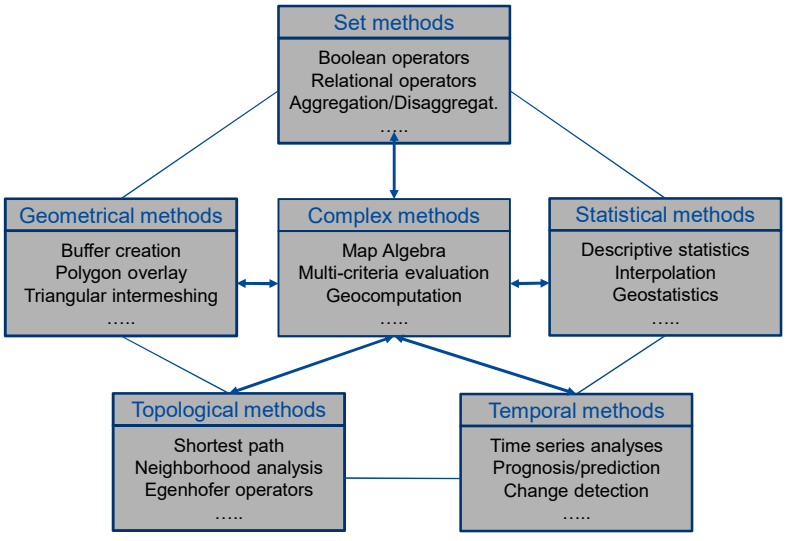
Analysis: 6 categories 1000's of analyses functions



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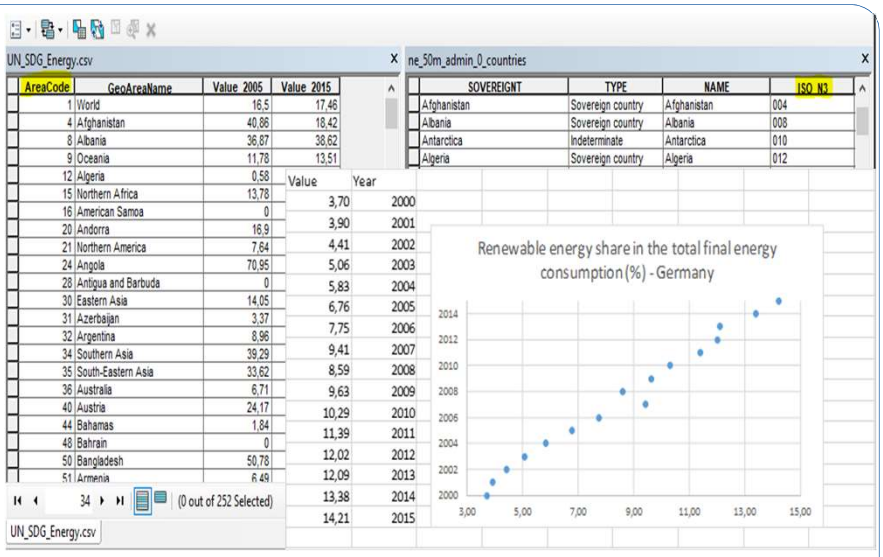
SDG: Join & Temporal statistics



AreaCode	GeoAreaName	Value 2005	Value 2015
1	World	16,5	17,46
4	Afghanistan	40,86	18,42
8	Albania	36,87	38,62
9	Oceania	11,78	13,51
12	Algeria	0,58	
15	Northern Africa	13,78	
16	American Samoa	0	
20	Andorra	16,9	
21	Northern America	7,64	
24	Angola	70,95	
28	Antigua and Barbuda	0	
30	Eastern Asia	14,05	
31	Azerbaijan	3,37	
32	Argentina	8,96	
34	Southern Asia	39,29	
35	South-Eastern Asia	33,62	
36	Australia	6,71	
40	Austria	24,17	
44	Bahamas	1,84	
48	Bahrain	0	
50	Bangladesh	50,78	
51	Armenia	6,49	

SOVEREIGNT	TYPE	NAME	ISO_N3
Afghanistan	Sovereign country	Afghanistan	004
Albania	Sovereign country	Albania	008
Antarctica	Indeterminate	Antarctica	010
Algeria	Sovereign country	Algeria	012

Value	Year
3,70	2000
3,90	2001
4,41	2002
5,06	2003
5,83	2004
6,76	2005
7,75	2006
9,41	2007
8,59	2008
9,63	2009
10,29	2010
11,39	2011
12,02	2012
12,09	2013
13,38	2014
14,21	2015

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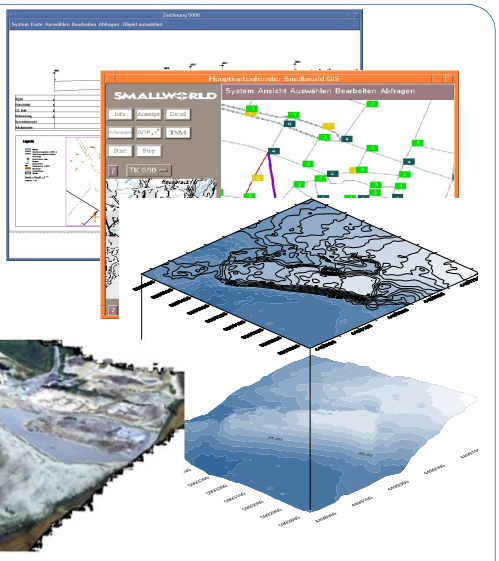
Presentation / visualisation of information in GIS

- In analogue form:
  - Maps
  - Detail- and overview plans
  - Sketches
  - Map diagrams
  - Business graphics
  - Perspectives
  - Imagery
  - Length-/transversal profiles
  - Reports
  - Statistics
  - Tables
  - Others



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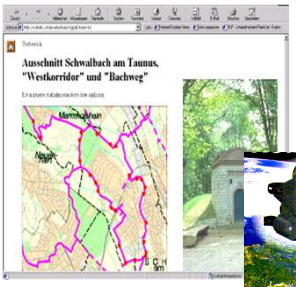
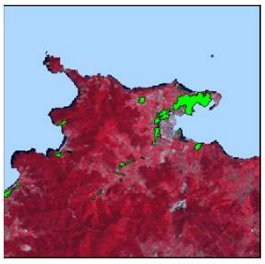
Presentation / visualisation of information in GIS

- In electronic/digital form:
  - Interactive on screen
  - Multimedia
  - Fly through
  - Virtual- or Augmented Reality
  - Animation
  - Digital data exchange
  - Others





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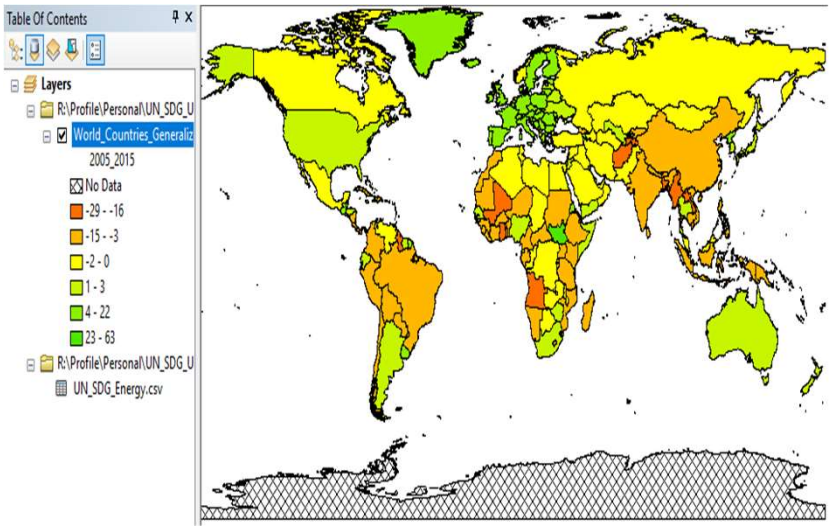
SDG: Visualising the results



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❖ PRODUCTS AND STANDARDS

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GIS desktop products

- Commercial products:
  - ESRI ArcGIS
  - Autodesk AutoCad Map 3D
  - Smallworld GIS
  - Intergraph G/Technology
  - ….
- Open Source products:
  - Quantum GIS
  - Geographic Resources Analysis Support System (GRASS)
  - OpenJUMP
  - ….

esri ArcGIS

QGIS

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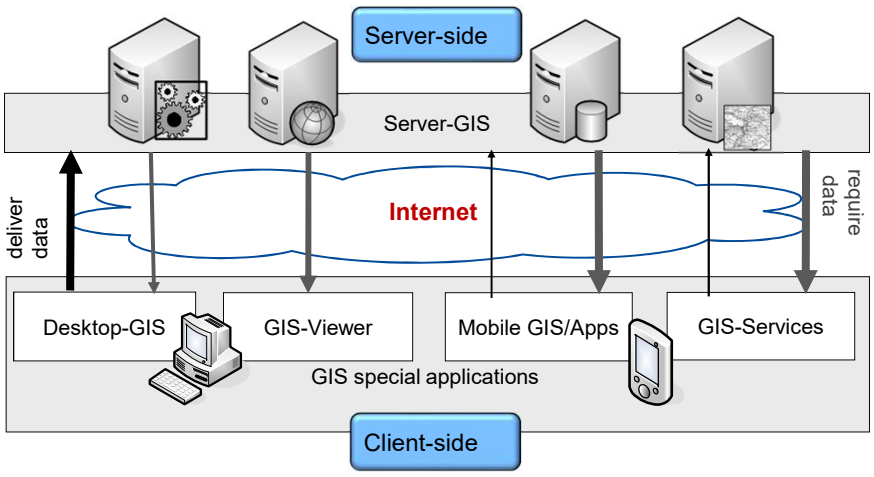
GIS product categories and their interactions



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Standardisation

- de-jure ⇔ de-facto
- Formal ⇔ technical

- Products: Paperware
- Goal: Formalisation and Interoperability


DEUTSCHE NORM Mai 2005

DIN EN ISO 19101 DIN

ICS 35.240.70

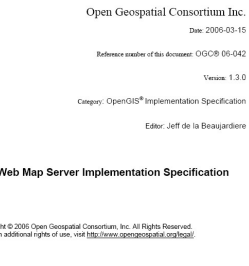
Geoinformation – Referenzmodell (ISO 19101:2002); Englische Fassung EN ISO 19101:2005

Geographic information – Reference model (ISO 19101:2002); English version EN ISO 19101:2005

Information géographique – Modèle de référence (ISO 19101:2002); Version anglaise EN ISO 19101:2005

Gesamtumfang 51 Seiten

Normenausschuss Bauwesen (NABau) im DIN


Open Geospatial Consortium Inc.

Date: 2006-03-15

Reference number of this document: OGC® 06-042

Version: 1.3.0

Category: OpenGIS® Implementation Specification

Editor: Jeff de la Beaujardiere

OpenGIS® Web Map Server Implementation Specification

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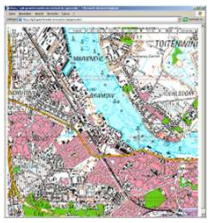
Open Geospatial Consortium: OGC Web Services

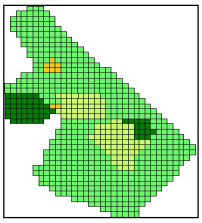
- **OGC Web Map Service (WMS)**
  - Access to raster maps/imagery (GIF/PNG/JPG)



- **OGC Web Feature Service (WFS)**
  - Access to features/vector data (GML)

- **OGC Web Coverage Service (WCS)**
  - Access to raster coverages

- and many others



https://www.ogc.org/

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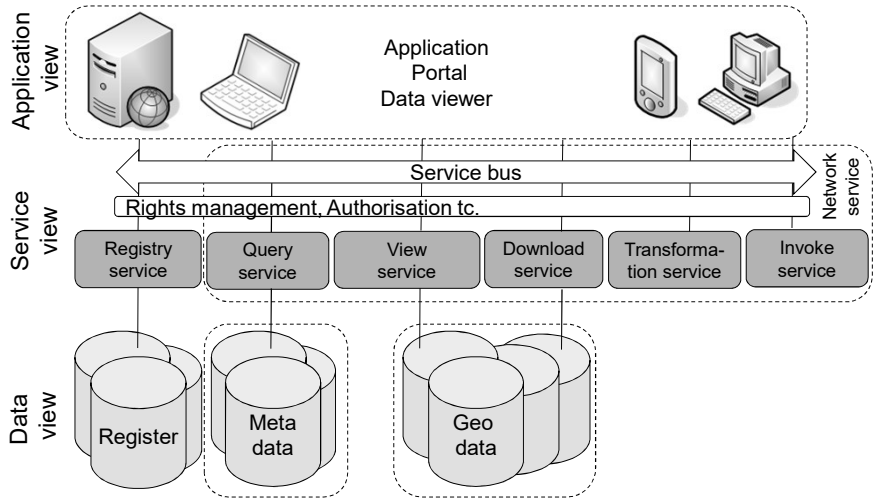
Web-based GI architecture



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APPLICATIONS

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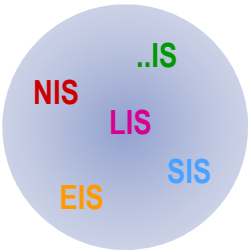

FROM LIS, EIS, NIS, .. TO ..IS

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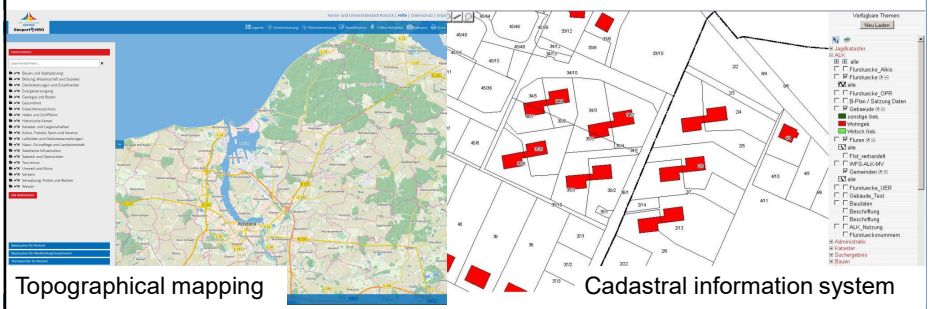
Land information systems / Mapping

- A **land information system (LIS)** is an instrument for decision-making in law, administration and economy as well as a tool for planning and development. It consists of a data collection containing land and topography-related data for a specific region. It includes procedures and methods for the systematic collection, updating, processing and implementation of this data. The basis of a LIS is a uniform, spatial reference system for the stored data, which also facilitates the linking of the data stored in the system with other geodata.



Topographical mapping

Cadastral information system

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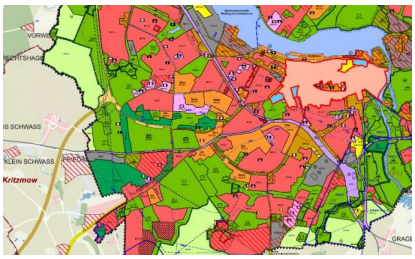
Planning information systems

- A **spatial planning and information system** is an instrument for decision-making and a tool for planning and development. It consists of data collections on population, economic and settlement development, infrastructure development, land use and resources, which are incorporated into regional development programmes. The procedures and methods for collecting, updating and implementing these data are also an essential part of the information system. The basis is the uniform spatial reference, linking the various types of data with each other.



Zoning plan City of Rostock

Detailled plan Pirmasens

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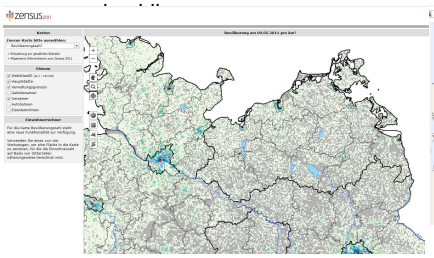
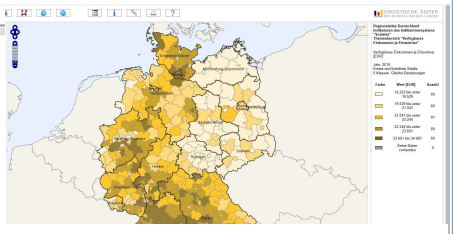
Statistical information systems

- A **statistical information system (SIS)** provides data obtained through statistical methods and collected using official statistics, business statistics, statistics from associa-tions and statistics from scientific institutions. The data is subject to special legal data protection regulations. In addition to the factual reference, the time reference (key date or period) and the spatial reference are the main characteristics of the statistical information. Users of statistical information systems range from public administrations (governments, parliaments, municipal institutions) to the economy and its associations, scientific institutions and the



Census 2011: Population density/km²



Regional atlas: Available income per inhabitant

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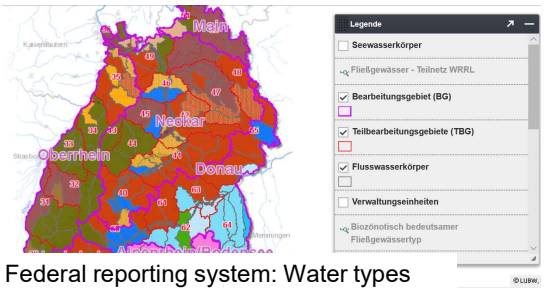
Environmental information system

- An **environmental information system (EIS)** is an extended GIS that serves to collect, store, process and present spatial, temporal and content-related data to describe the state of the environment with regard to pressures and hazards and to form the basis for environmental protection measures. (Page & Jaeschke & Pillmann, 1990).



Federal reporting system: Water types

Monitoring network
Local gamma dose rate

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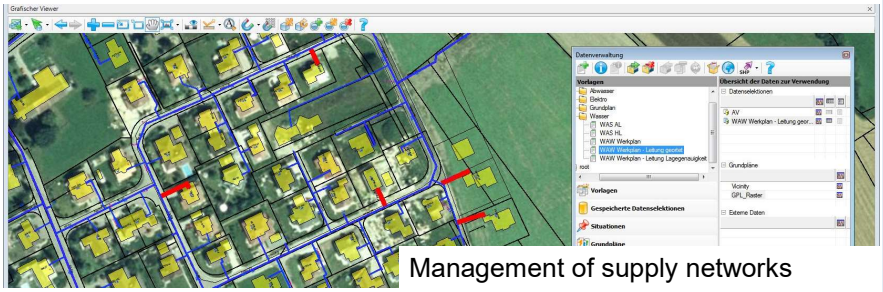
Network/Utility information systems

- A **network information system (NIS)** is an instrument for the collection, management, analysis and presentation of equipment data in supply and disposal companies. This includes data on the network and facilities for supply and disposal as well as customer data. The supply network with its operating resources, the existing relationships between them and the processes running on them are modelled, recorded, evaluated and visualised. The network documentation usually refers to the network topology, which must be given in a uniform reference framework. NIS are used for network planning, network operation and maintenance (FM systems).



Management of supply networks

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..IS characteristics

GIS type	Data type	Dimension				Scale
		Geometry	Topology	Thematics	Temporal	
LIS	Vector/ (Raster)	2D, 2.5D, 3D	2 (Meshes) 3 (Solids)	low	static	large-small
NIS	Vector	2D, 2.5D	0 (Nodes) 1 (Edges) 2 (Meshes)	mean	static	large-mean
SIS	Vector/ Raster/ Hybrid	2D-(3D)	2 (Meshes) 3 (Solids)	large	static to slowly changing	large-small
EIS	Vector/ Raster/ Hybrid	2D-3D	2 (Meshes) 3 (Solids)	large	static to highly dynamic	large-small

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AGRICULTURE, FORESTRY ETC.

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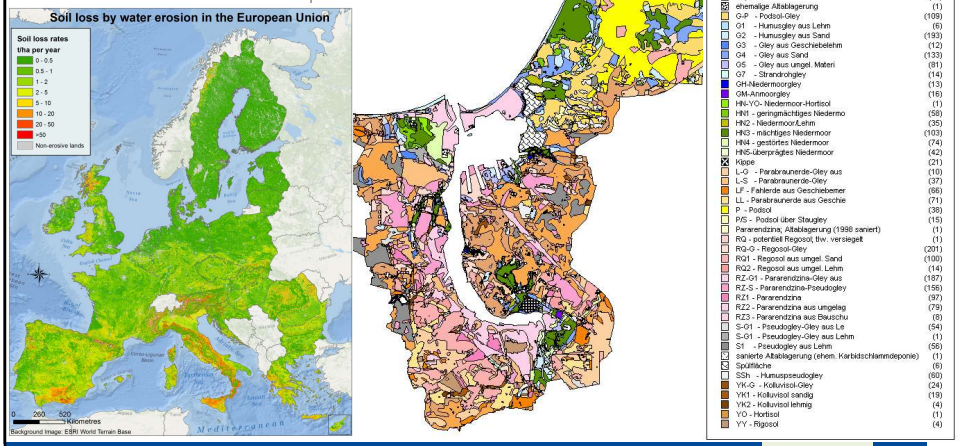
Agricultural IS - Soil information

- Soil loss by water erosion in EU
- Soil type mapping in Rostock



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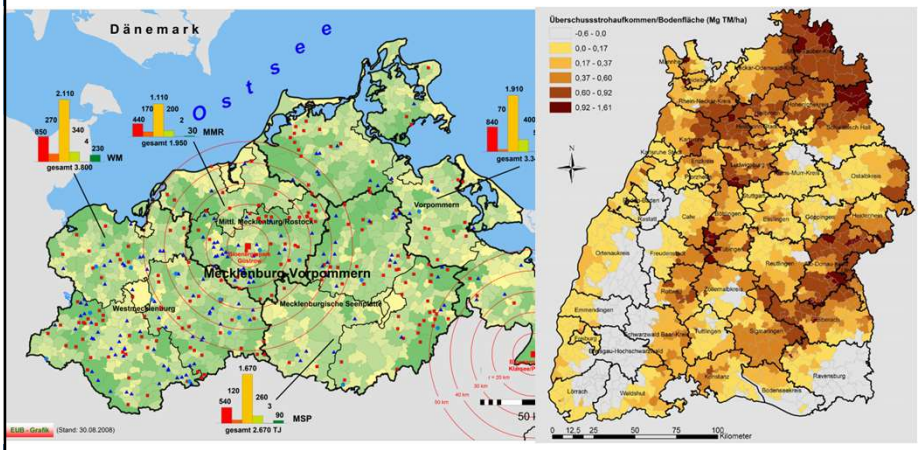
Agricultural IS - Renewable energies

- Power production from biomass
- Energy production from organic waste



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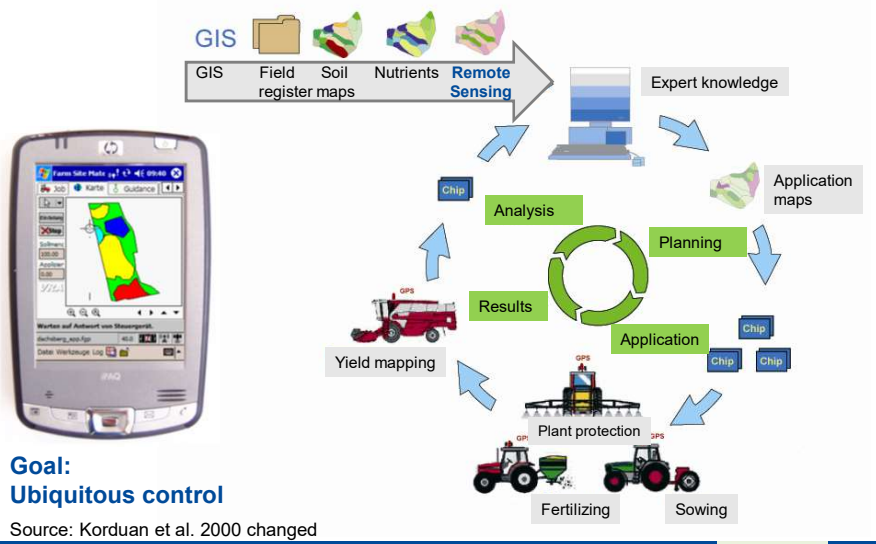
Agricultural IS – Smart/Precision Farming



Goal:
Ubiquitous control

Source: Korduan et al. 2000 changed

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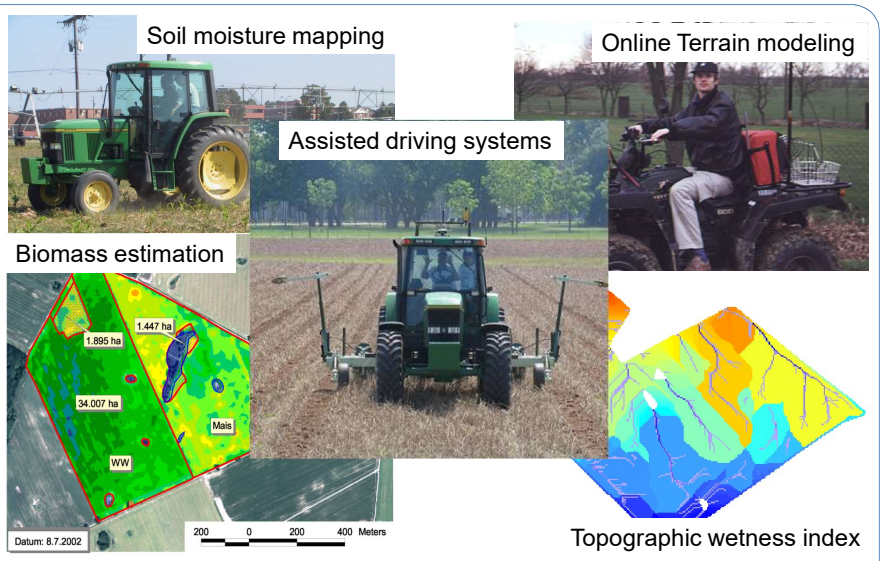
Agriculture – Smart/Precision Farming



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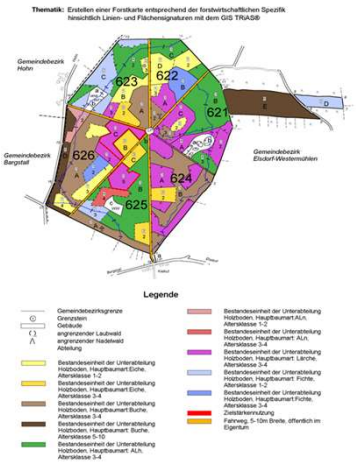
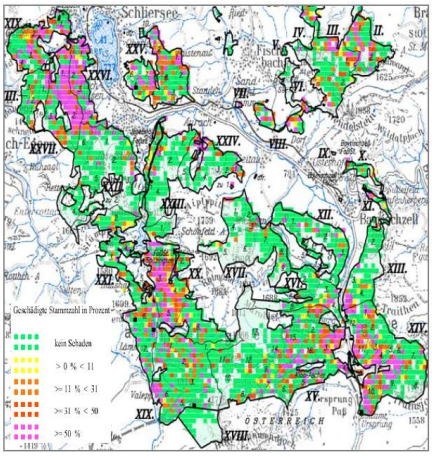
Forestry

- Forest mapping



- Forest inventory



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RESEARCH

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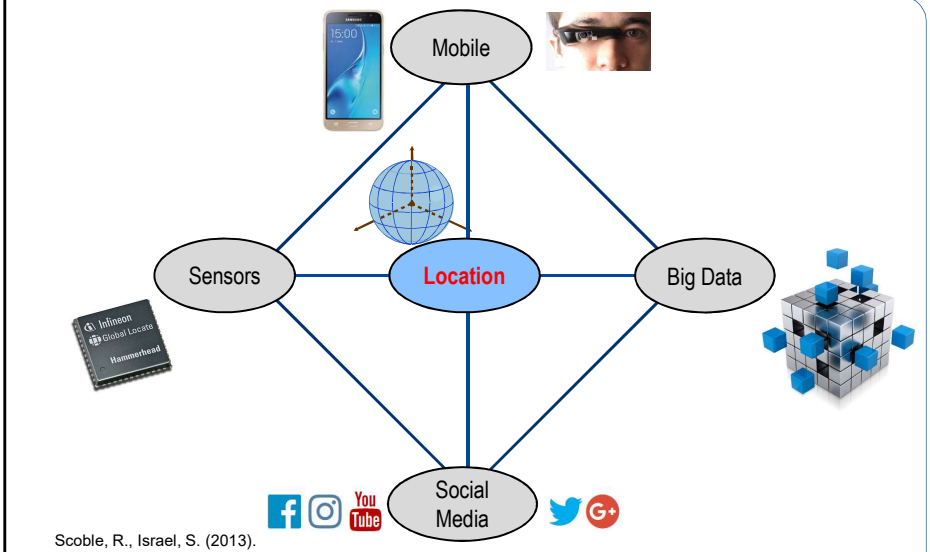
5 driving forces in a digital world of the future



Scoble, R., Israel, S. (2013).

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Sensors – new ways of data acquisition

Photo: Hitachi

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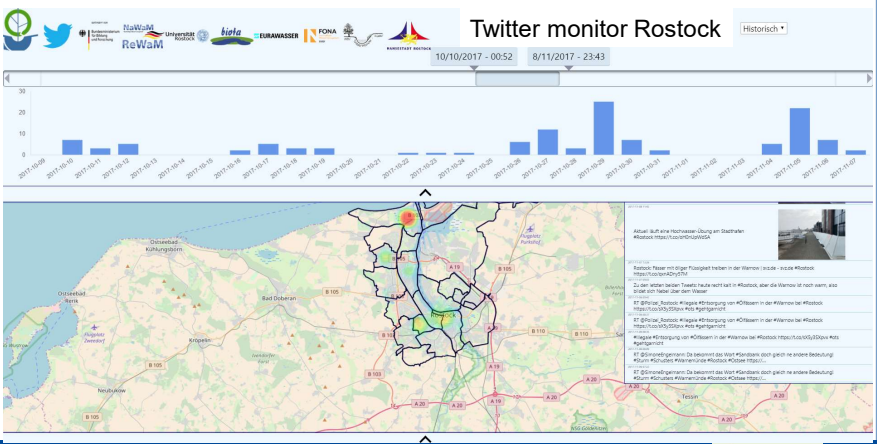
Social media

- Connecting people
- Users as prosumers (producers and consumers of data)
- Data on individuals (data protection issues)



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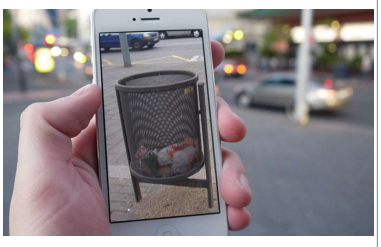
Mobile

- Our mobile devices (Smartphone/Tablet) will become classical user interfaces to GIS.



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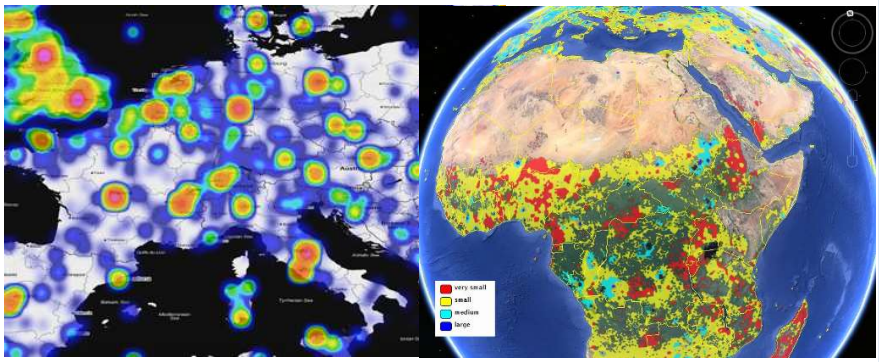
Big data

- Big data: extremely large data sets that may be analysed computationally to reveal patterns, trends, and associations, especially relating to human behaviour and interactions.
- **5 V's: Variety, Volume, Veracity, Velocity, Value**
- Data analytics, data driven science



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TAKE HOME MESSAGE

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GIS
– in simple terms –

- is a computer-based system capable of holding and using **data describing places on the earth.**
- **links spatial data with context** about a particular feature on the earth.
- doesn't hold maps or pictures - it runs a **database**. The heart of any GIS is the database through which questions such as what a feature is, where it is, and how it relates to other features can be answered.
- gives you the ability to **associate information with a feature on the earth** and to **create new relationships** that can determine the suitability of various sites for development, evaluate environmental impact, identify the best location for a new facility, and so on.
- turns **data** into information and **information** into **knowledge** by spatial analysis.
- encourages **cooperation** and **communication** among different users.
- is an **analytical tool**.
- stores the data from which you can **draw a desired view to suit a particular purpose**.

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LITERATURE

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Literature

- Textbooks

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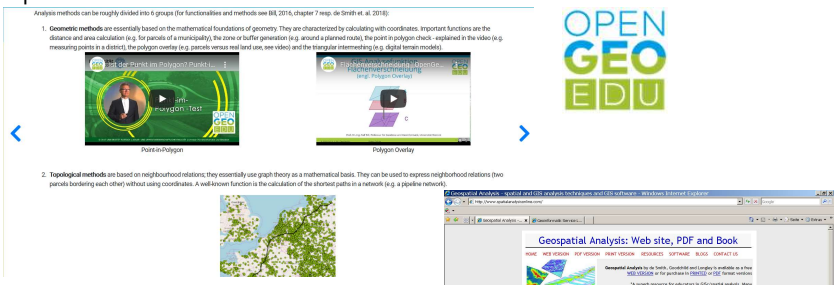
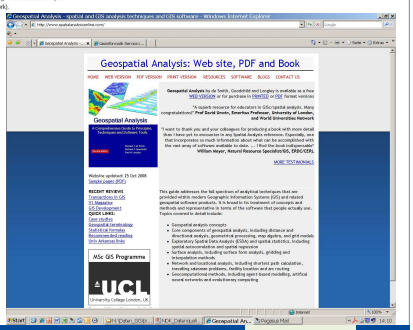
eLearning

- Open Educational Resources





- https://learn.opengeoedu.de/en/gis/
- http://www.spatialanalysisonline.com/

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PROJECT DIVECROPS

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DAAD

- Funded by:
  - DAAD – deutscher akademischer Austauschdienst (German Academic Exchange Service)
- Project duration:
  - 01.01.2019 - 31.12.2022
- Coordinator:
  - apl. Prof. Dr. habil. Bettina Eichler-Löbermann, Pflanzenbau, Universität Rostock (UROS)

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