Thematic cartography

Source: Dr.-Ing. Li Zhang, Lecture Thematic cartography
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Introduction

A map is a planar, full-scale, generalized and content limited model of spatial information. Cartography is a discipline, dealing with the conception, the production, the distribution and the field of study of maps.

Tasks of cartography

- Processing and transfer of spatial related information(interpretation, choice, generalization, presentation)
- Compilation, design
- Realization, distribution

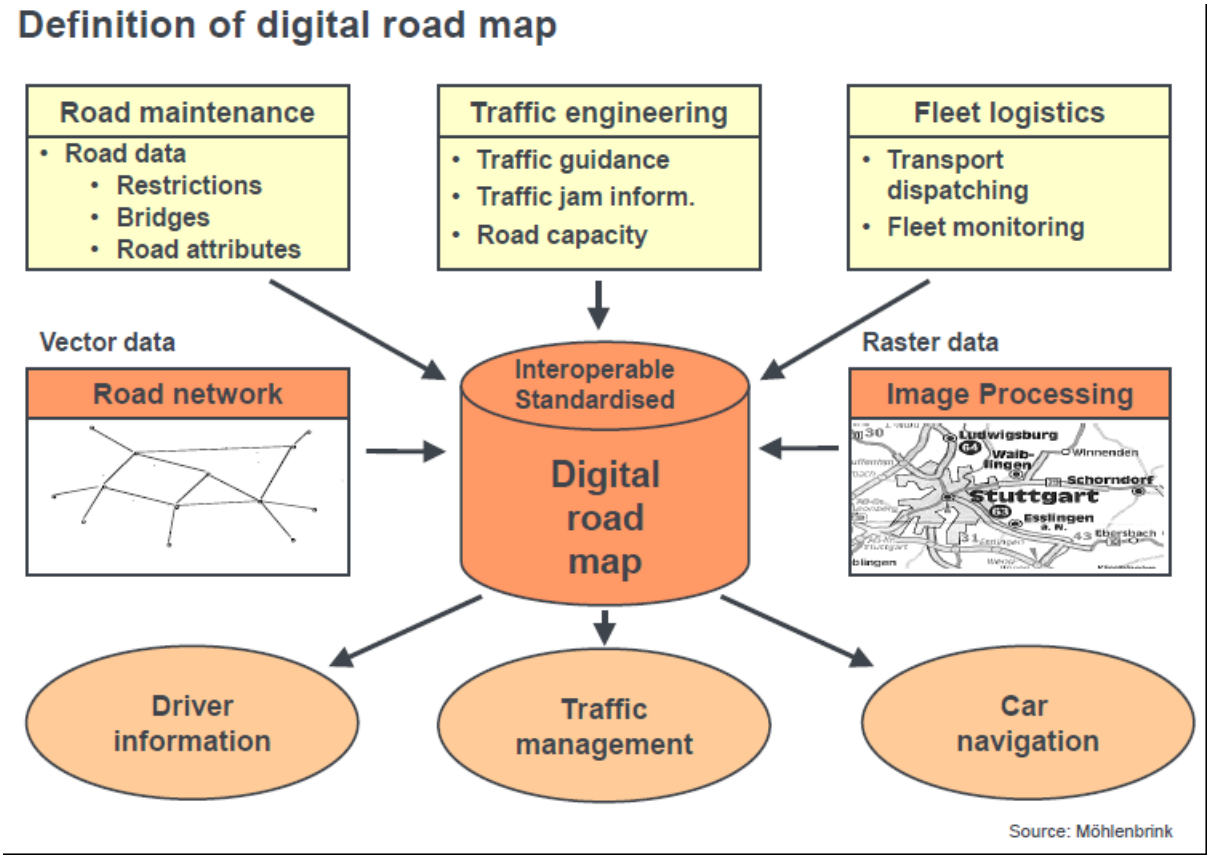
Classification of maps

- Kind of realization
  - Analogue
  - Digital
- Producer
  - Official
  - Private
- Way of origin
  - Base map
    - the base maps deliever a part of thematic data
    - further data can be collected from other sources
  - Derived map
- Size of map scale
  - Large scales: >1:10,000
  - Medium scales: 1:10,000 ~ 1:300,000
  - Small scales: <1:300,000
- Content
  - Topographic map
  - Thematic map

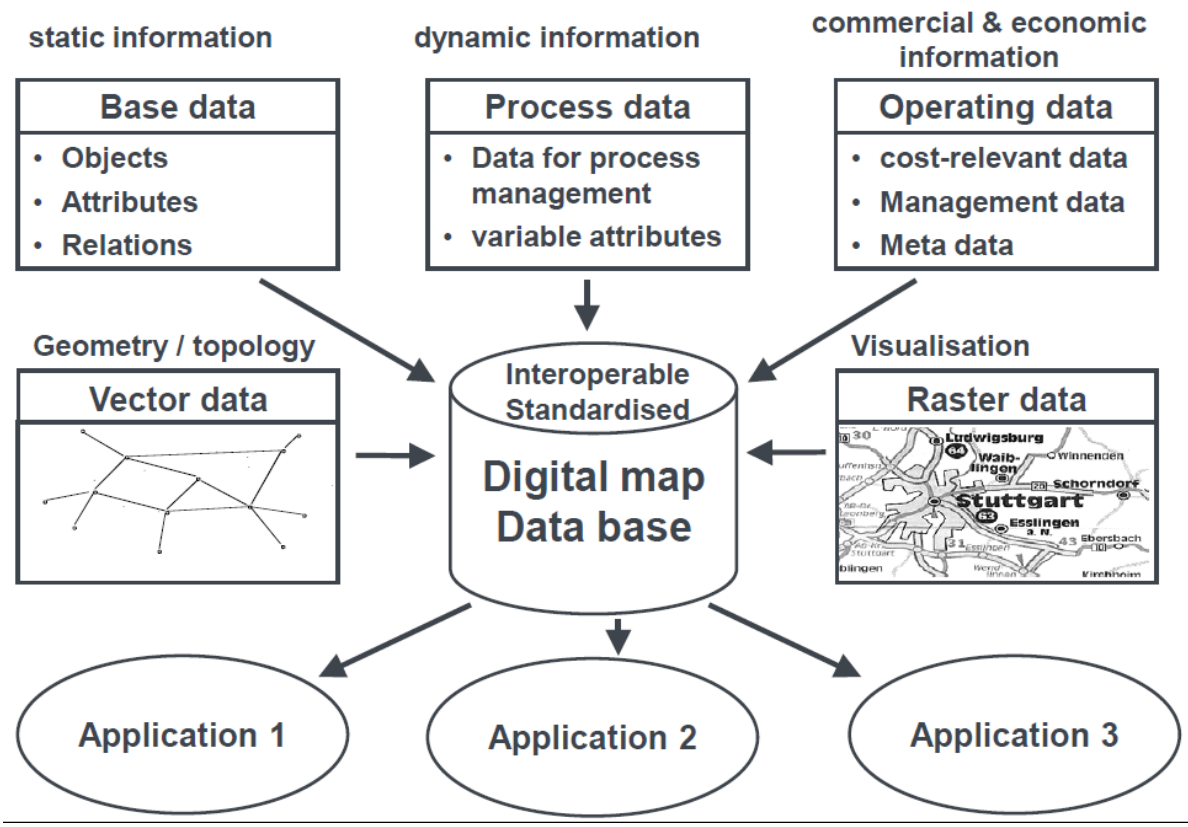
    - Analytical and synthetic
    - Primary and derived(source) maps
    - Concrete and abstract maps
    - Inductive and deductive maps
    - Representation of unchangeable and changeable issues
    - Representation of bounded and continuous issues
    - Map and cartograms
    - Large scale and small scale maps
    - Single maps, map series, atlases
- Map types(method-oriented structure): Point maps, isopleth maps, areal maps, signature maps, diagram maps...

Maps are never completely objective but they should transfer the highest level of objectivity - due to the different methods of generalization for map visualization

Definition of digital map



Definition of digital road map



Geodata

Data about objects, land forms and infrastructure on the earth's surface, resource.

- Essential characteristic - spatial relation
  - Geo data can be linked by its spatial relation
  - New information can be derived by using gis functionalities
  - Queries, analysis, and processing of certain questions and problems
- Describe the land scape's objects
- Two partitions
  - Geo/spatial base data
  - Geo/spatial thematic data
- Describes objects, directly(coordinates) or indirectly(relationship) referenceable by its position in space
- Information technology, geo data - combination of data

    - Geometric data(position and shape of objects)
    - Topology(spatial relations)
    - Graphic representation
    - Thematic data, attributes
- Geoinformation is a property, which has to be provided, administrated and maintained (to guarantee up-to-dateness)
- Geo information has to be managed. Besides the actual core data, metadata has to be provided as well
- specific and unique characteristics
    - Spatial relation: The information has a spatial location, e.g. by coordinates, addresses, indices or other forms of spatial reference
    - Portable: unbounded usage through world-wide networks
    - Divisibility: Information can be sent out and can be received
    - Extensibility: Value of information increases with frequency of usage
    - Compressibility: Information can be aggregated to support different application levels

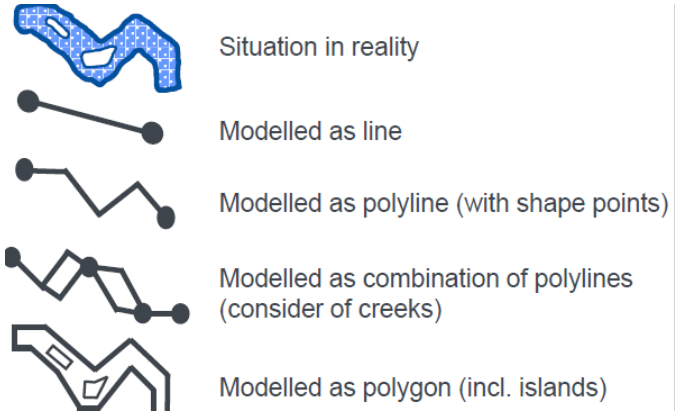
Map series

Classification

- content
    - **Topographic maps**: landscape is represented in a characteristically simplified way(situation(building, roads, rails), waters, terrain profile, vegetation,...)
    - **Thematic maps**: phenomena and facts about the perception of the information are represented(e.g. cadastral maps, planning maps)
- Realization
    - Analogue: have to be brought into a computerized form by digitization
    - Digital: already available in a computerized form and can be imported

Modelling within map series

can be modelled and represented by different object types and in various levels of detail



Topographic maps

landscape is represented in a characteristically simplified way: main objects - situations(buildings, roads, rails), waters, terrain profile, vegetation and a number of other phenomena

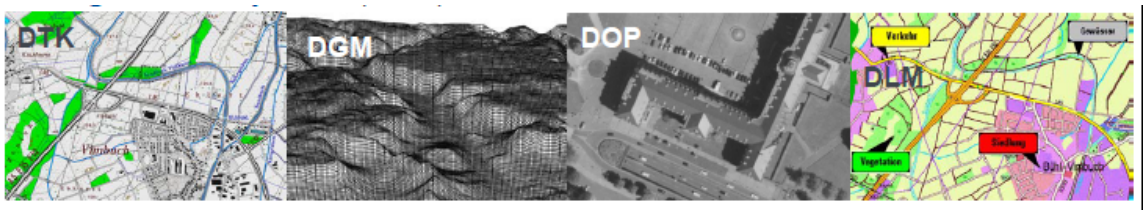
Description and scale	Reference	Source
Topographic base maps in Baden-Württemberg (Note: digital maps ALK are now used in place of analogue maps)		
German Base Map 1:5000	DGK 5	County surveying authorities
Topographic maps		
Topographic maps 1:25 000	TK 25	State surveying authorities (www.lv-bw.de)
Topographic maps 1:50 000	TK 50	
Topographic maps 1:100 000	TK 100	
Topographic overview maps		
Topographic overview maps 1:200 000	TÜK 200	Federal Agency for Cartography and Geodesy (www.bkg.bund.de)
Overview maps 1:500 000	ÜK 500	
International map of the world 1:1 000 000	IWK 1 000	

topographic maps in germany

roman characters indicate the map scale

- series of numbers indicate the location
  - first both for north-south-direction: 00 (=N) to 87 (=S)
  - last both for west-east-direction: 00 (=W) to 50 (=E)

- the normal release of the topographical map contains four layers
  - planimetric representation and text - black
  - waters - blue
  - contour lines - brown
  - forests - green
- ATKIS: official topographic cartographic information system(TOLG)



  - DTK - digital topographic map (Topographische Karten)
  - DGM - digital terrain model (Geländemodelle)
  - DOP - digital ortho photo (Orthophotos)
  - DLM - digital landscape model (Landschaftsmodelle)

Thematic maps

- phenomena and facts about perception of the information
- types of the thematic maps
  - nature: geology/soils/temperature
  - anthropological: law/settlement/planning
- cadastral maps
  - land survey register maps proves the partitioning of the ground with field parts and indicates their location, size and kind-of-use
  - three parts

  - catastre numbering series with survey sketches and coordinate catalogs
  - cadastral map series: field parts with their number and boundary, buildings, topographical objects and kind-of-use
  - cadastral book series: field parts with their area, ownership, location, kind-of-use and result of official land classification for valuation purposes
- integrated AFIS – ALKIS – ATKIS-model(AAA-Model)
  - AFIS: official bench mark database(gravity, heights,...)
  - ALKIS: official land property cadastre information system
  - ATKIS: official topographic cartographic information system
- maps of settlements
  - geographical settlement maps provide information on types of settlement, structure(downtown, borderland, kind of build-up area), function(administration, industry, traffic, grassland, etc.) and formation of the settlement
  - map with large to medium scale(city maps, property maps, topographical maps) are the bases for thematic city maps
- maps for spatial planning

- general planning: land development plan, regional plan, land use plan, local development plan

<table>
<tr><th>Level</th><th>Title</th><th>Scale</th><th>Base maps</th></tr>
<tr><td>Federal State
(e.g.: Baden-Württemberg)</td><td>land development plan</td><td rowspan="2">1 : 500 000
to
1 : 25 000</td><td rowspan="2">• Topographical maps
• Aerial photos
• Satellite images</td></tr>
<tr><td>Region
(e.g. `Region Neckar-Alb')</td><td>regional plan</td></tr>
<tr><td rowspan="2">City
(e.g. `Tübingen`)</td><td>land use plan</td><td>1 : 25 000
to
1 : 10 000</td><td rowspan="2">• Topographical maps
• Cadastral maps
• City maps</td></tr>
<tr><td>local development plan</td><td>1 : 1 000
to
1 : 500</td></tr>
</table>

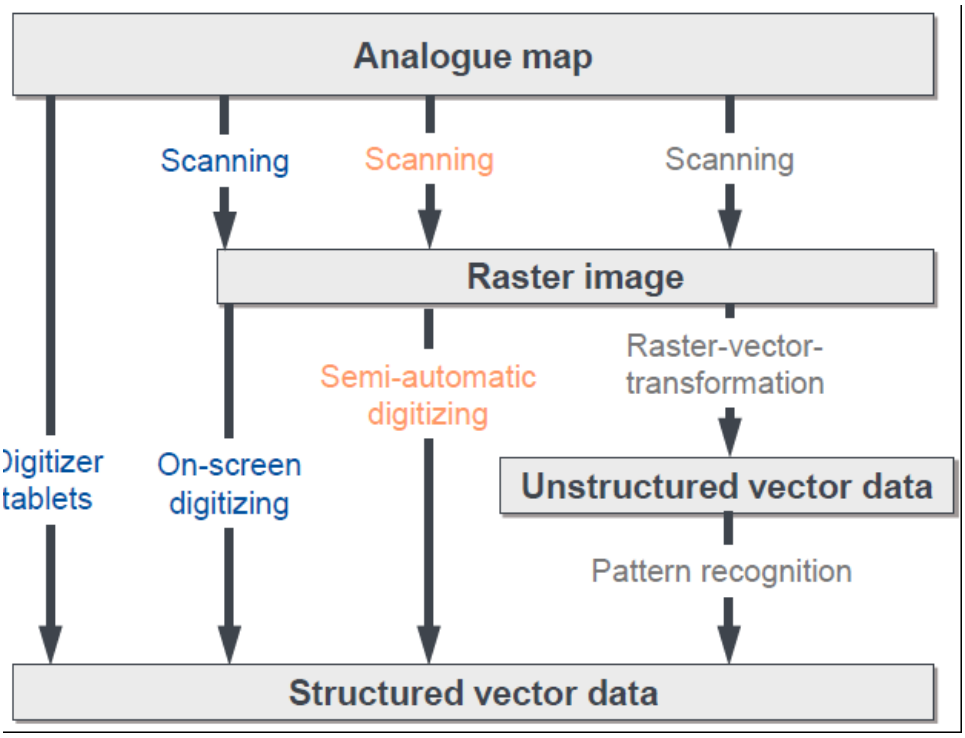
- department planning
  - representation of redevelopment of specific sections, e.g. transport routes, agrarian structure, recreation areas
  - large scale maps
  - technical view of departmental planning
- GDF: geographic data file
  - standardized format for geodata in transport/traffic section
  - GDF describes a system for the exchange of digital traffic geoinformation, consider the requirements of the application in section of street transport and transport telematic
  - data structure: specified in object, attribute, and relationship catalogues
    - object/features
      - road elements/roads

        - junctions/intersections
    - attributes
        - street name
        - direction of traffic flow(DF)
    - relations: turn restrictions
    - GDF vs. ATKIS
        - GDF: integration of a junction, for each lane, there is an own road element
        - ATKIS: new object due to attribute change

Data processing

Digitizing

Digital methods



- manual
    - digitizer tablets
        - acquisition of coordinate pairs

        - identification of point
        - the integrated grid provides coordinates w.r.t. the reference frame defined by the software
    - on screen digitizing
        - digital acquisition of geometry directly on the screen
        - raster data in the background are used to create a digital representation of the objects found in the raster data(e.g. satellite image)
- semi automatic
    - a line is automatically traced down within an analog map using a sensor
    - start and end of the line as well as crossroads have to be entered manually
    - advantage: faster than manual digitalising
    - disadvantage: complex and expensive hardware
- automatic
    - scanning: the analog image is transformed into a digital image(raster data)
    - raster-vector-transformation: the captured raster data(grid) is transformed into vector data. In order to derive areas, symbols and fonts for object recognition
    - pattern recognition: image processing

Digitizing hardware

digitizing workplacedrum scannerflatbed scanner

Digitizing software: ArcGIS

- homogenization: geometric restrictions were applied to the result of digitization. This is to ensure quality and contour accuracy.
    - rectangularity, straightness, parallelism
    - large scale
- possible sources of error: overlap and gap

- solotions: GIS support edit-functions like complete, copy, delete,...

Data processing

georeference and coordinate transformation

- importance
  - get the other points in the map as accurate as possible
  - represent new data in the right place
- georeferencing: assigns a reference system to a data set
  - geodetic datum: a set of parameters and points used to exactly define the 3D shape of the earth
  - coordinate system: consists of two or three coordinate axes and/or reference bearing within a plane or space
  - map projections: the mathematical relationship between an ellipsoidal or spherical earth model and the mapping plane. - define the transformation from a 3D earth model into 2D coordinates
- transformations

Transformation	Parameters	Min. number of identical points	Application
3 Parameters	• Translation in X and Y • Rotation	2	Measurement with fixed scale
4 Parameters	• Translation in X and Y • Scale • Rotation	2	Standard case
5 Parameters	• Translation in X and Y • Scale in X und Y • Rotation	3	Direction-dependent paper distortion
6 Parameters	• Translation in X and Y • Scale in X and Y, • Rotation • Shear of the axes	3	Deformation of the axes multi-parameter
Rubber sheeting	• Differential equalization	n	Paper distortion, Unknown map projection and Generalisation

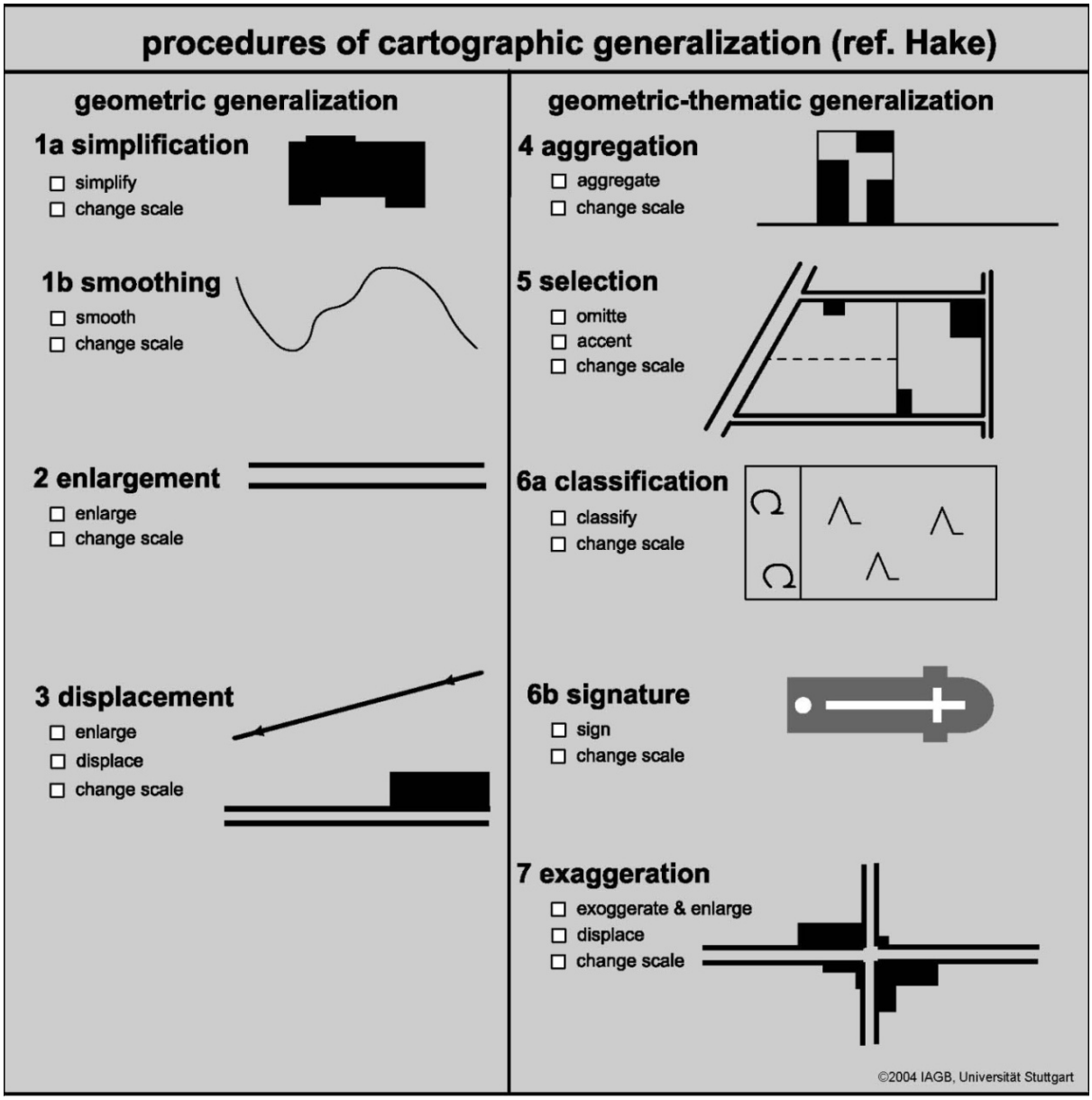
  - Euclidian - 3 parameter, 2 points
    - translation in X and Y, rotation - 3 parameters

        - measurement with fixed scale
    - similarity - 4/5 parameter, 2/3 points
        - translation in X and Y, rotation, scale
        - standard case/ direction dependent paper distortion(scale in X and Y)
    - affine translation - 6 parameter, 3 points
        - translation, rotation, scale, shearing
        - deformation of the axes multi-parameter
    - rubber sheeting
        - all data points are adjusted in order to achieve a better correlation at a small number of known points within the data set
        - connections between elements within a dataset(topology) remain the same
        - distances between points are changed by expansion, contraction or other manipulations
        - application: paper distortion, unknown map projection and generalisation
- distortion of maps
    - analog
        - generalization
        - storage(vertically hanging maps)
        - folding of the map
        - production process
    - digital
        - map projection
        - generalization
        - incorrected coordinates
        - individual data sources

Matching & merging

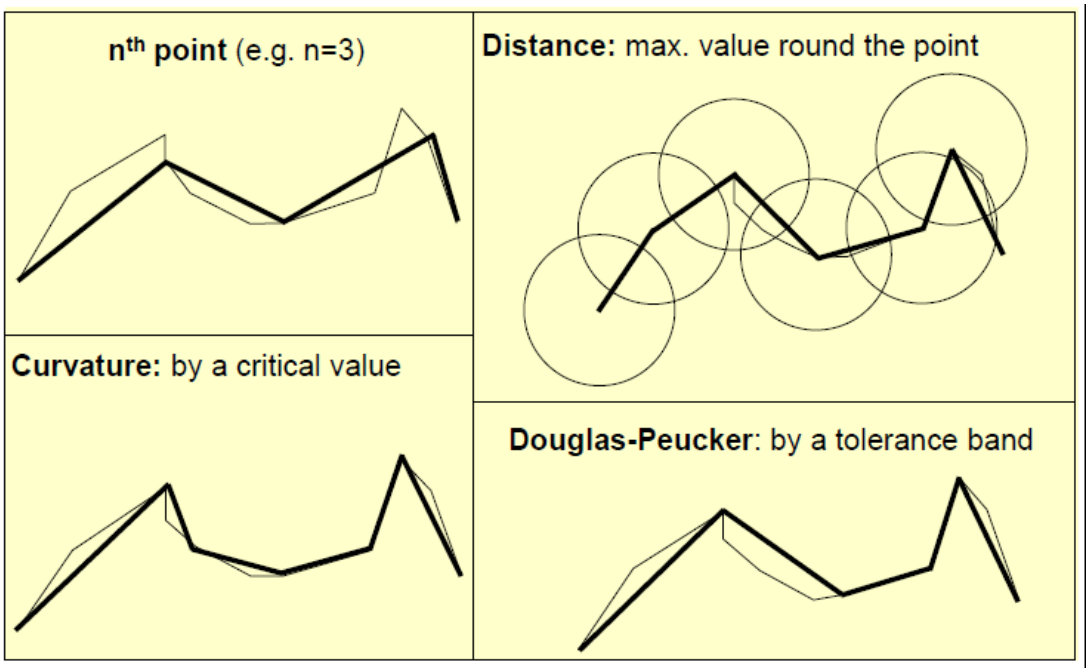
- map matching: absolute coordinates are transformed into local coordinates within the graph
- edge matching
  - comparison and adjusting of edge along the borders of the digital map or other saved units
  - goal: agreement in position, form, and attributes
- merging
  - join objects(line, polygon) from the same or different data sets into one data set
  - forms
    - geometry
      - Deletion of Duplicates
      - Changes in topology/ deletion and insertion of identical points
      - Geometric adjustment/ extension and contraction of objects
    - attributes
      - usage of segmented attributes
      - add the information as attribute tables linked to the objects - a fully automatical process is not possible because the classification of different kinds of information have to be done manually
      - choose new object segmentation
      - generalization of information
    - relations: introduction of relations between service station and road network

Generalization

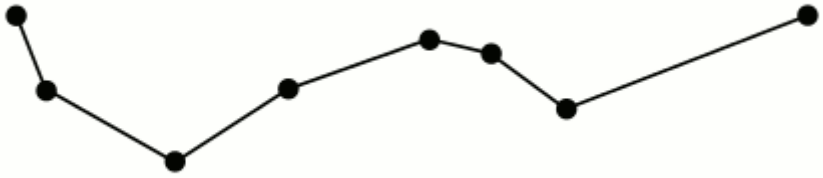


- visualization of the same information in different(usually smaller) scales
- derived from orthophoto
  - simplification, smoothing, classification, creating signatures, evaluation
- advantage - definition
  - reducing the information content of maps due to scale change, map purpose, intended audience, and/or technical constraints
- disadvantage
  - main problem: geometric distortion - streets are wider and buildings are displaced and combined

    - loss of details
- digital data storage reduction, scale manipulation, statistical classification, symbolization
- line smoothing
    - there are more coordinates contained in the data set than needed to define the line or polygon
    - decrease the number or coordinates
    - simplification of lines by mean of vector procedures



    - douglas-peucker line smoothing: check whether a point is outside the tolerance band. If yes, draw a straight line to the point furthest away https://upload.wikimedia.org/wikipedia/commons/3/30/Douglas-Peucker_animated.gif



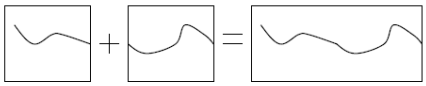
- semantic generalization
  - creation and classification of object classes
    - content: data have to be classified by an appropriated method
      - class limits: upper and lower limit of each class
      - class interval or width and mid-point of class
    - graphical aspect: choice of an appropriated display
  - choice of a framework: geographic/geometric/administrative

		Kind of classification	example
geographic	point out the real distribution and connection between facts and function	Natural border	drainage area 流域
area of similar characteristic	extensive data collection	Synthetic border	economic area
administrative	Constant frame work Cheap and fast in creation Easy to computerize	Public rights	town (borough, district), federal state
administrative (synthetic) areas	Only for small scales No details inside a single area	Private rights	real estate 房地产
geometric	Equal dimension of each area Easy comparison between the area	Dependent on coordinates	system of land survey
Grid	Transfer of the framework in reality Display depend on the random location of the framework	Independent on coordinates	random system of squares, rectangles

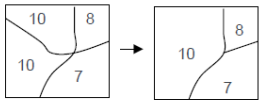
Data analysis

aggregation: information is not only in one dataset

Merge: add two or more data in one layer



Dissolve: simplify data with respect to the values of the attributes

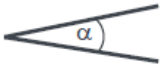


Clip: cut out a certain area

measuring, counting, calculating

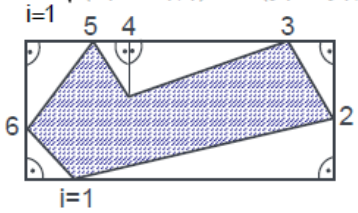
1. angle / direction

$$\alpha = \arctan\left(\frac{y_1 - y_2}{x_1 - x_2}\right)$$



2. Perimeter

$$U = \sum_{i=1}^{n} \sqrt{(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2}$$



3. area

(with Gauss trapezium algorithm, using the coordinates of the polygon vertices):

$$F = 0{,}5 \sum_{i=1}^{n} x_i (y_{i+1} - y_{i-1})$$

4. centroid

$$x_c = \frac{1}{6F} \sum_{i=1}^{n} (x_i + x_{i+1})(x_i + y_{i+1} - y_i + x_{i+1})$$

$$y_c = \frac{1}{6F} \sum_{i=1}^{n} (y_i + y_{i+1})(x_i + y_{i+1} - y_i + x_{i+1})$$

overlay: determine whether two area objects overlap, to determine the area of overlap, and to define the area formed by the overlap as one or more new area objects

attributes are transferred to the new objects Boolean logic operators(And, or, not)

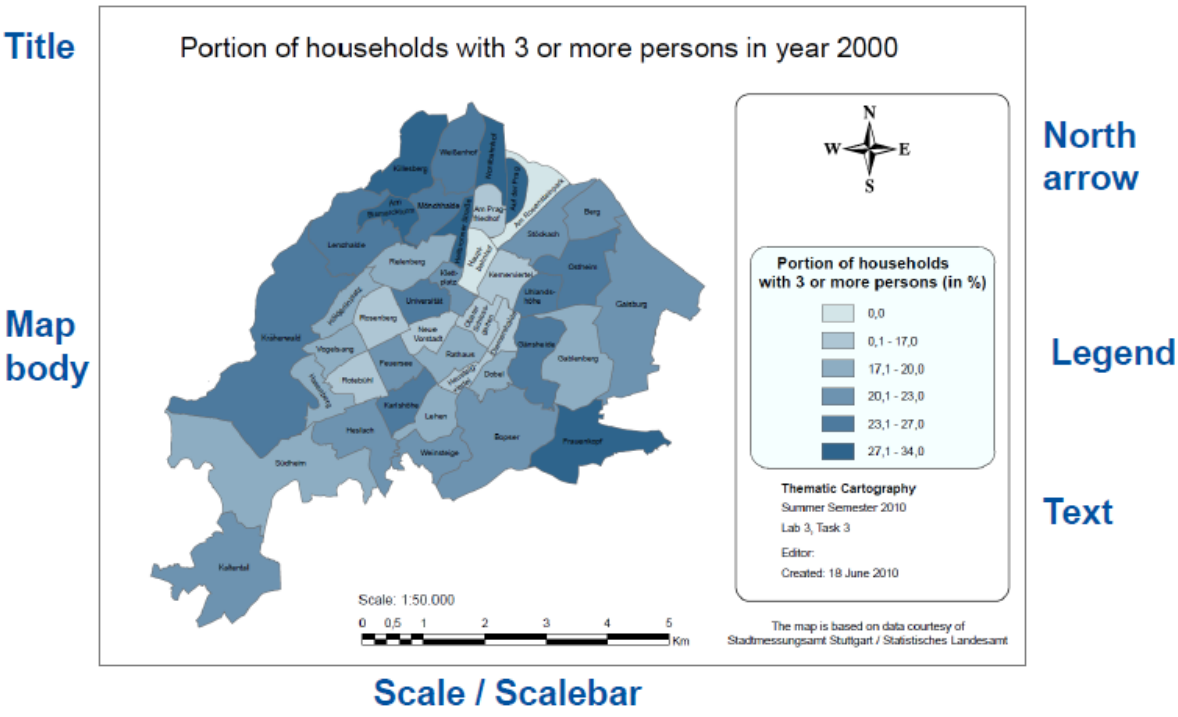
digital terrain model(DTM)

interpolation of pointscalculation of contour linescalulation of visibility3D visualization

Thematic maps

map elements: graticule, map content and map margin

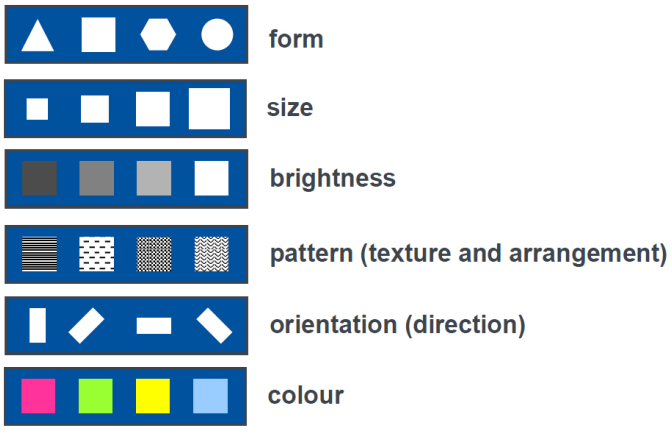
Map elements



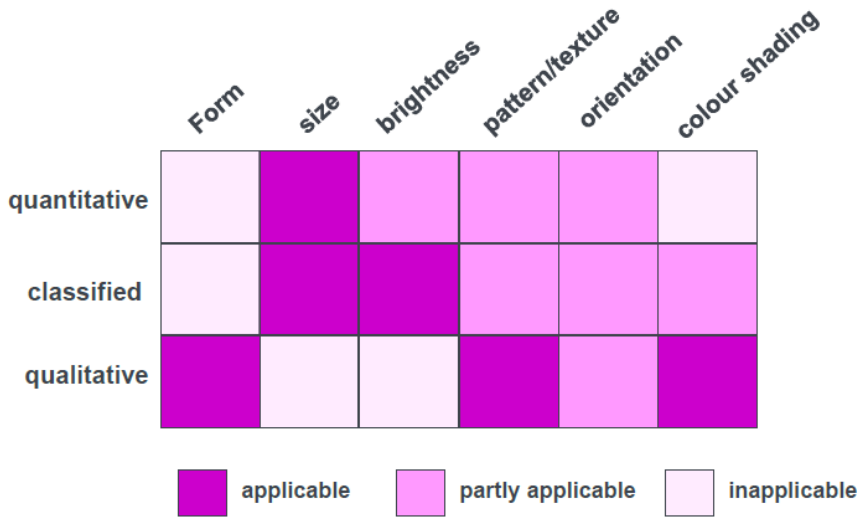
Graticule

Map content

- Visual variables

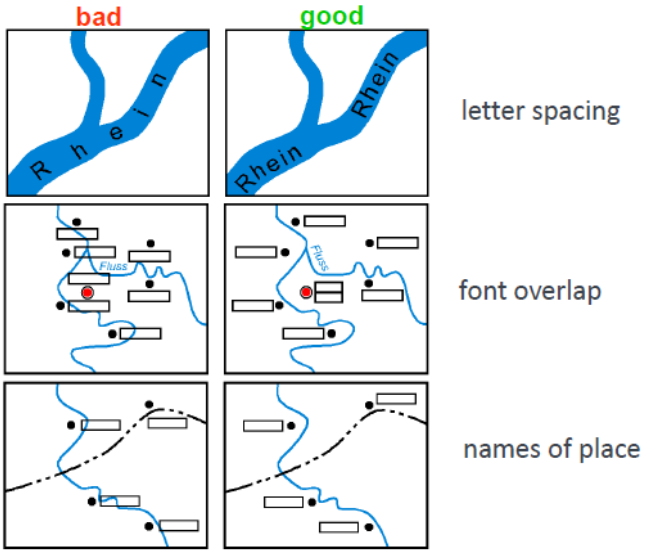


- Map Coloring



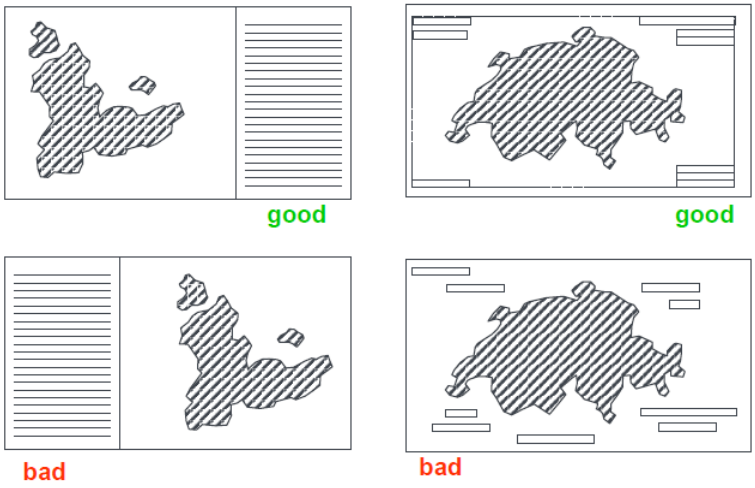
- conjure up associations for cleanness
  - natural colors(forest=green, water=blue,..)
  - symbolic colors(black = coal; blue = iron; yellow = gold; climate/ temperature: red-orange-yellow = warm, blue-green = cold; ...)
- little-much visualized as bright-dark
- symphony of colors
  - strong colors for small faces
  - subdued, neutral colors for the background
- differentiability of the color ranges: max 12 different colors in one map, better only 6-8
- accurate interpretability is more important than the cartographer's favourite colors

- map fonts

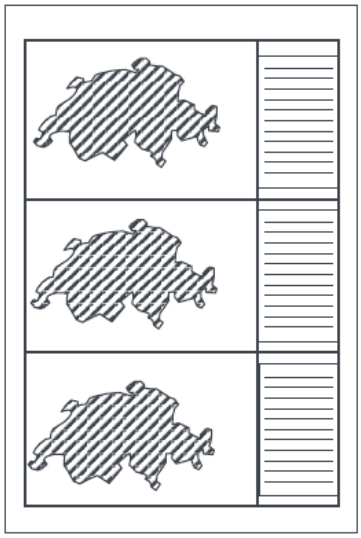


- intention of using fonts
  - comment on the topic and the visualization of the map: title, legend
  - create georeferences inside the map: geographic names, graticule
- fonts as symbol
  - classes: systematic use of character sets, size, style and color
  - hierarches: systematic use of upper/lower case, size, style and brightness
  - geographic names
  - places: positioning, enlargement
- Properties of map fonts
  - single words or small complex phrases
  - No fixed rows or columns
  - Linked with objects
  - Not only placed horizontally
  - Placed diagonal or curved type
  - Implied object ranking
  - In front of homogeneous background

        - rapidly understandable
    - Criteria for font styles
        - Simple character sets
        - Not only upper cases
        - Neither too small nor wide
        - Use bold fonts only in exceptional cases
        - Only use a few fonts within one map
        - justifiable!
    - rules for text placement
        - areal features: horizontal or in direction of greatest extension
        - linear features: parallel to the line
        - point feature: at the above right of the signature
- organization of map elements



Legend parts should always be presented as connected blocks



worse because of the confining frames

- resulting in visual harmony and balance
- avoid to place legend parts without a recognizable order principle on the map
- legend parts should always be presented as connected blocks

Map margin

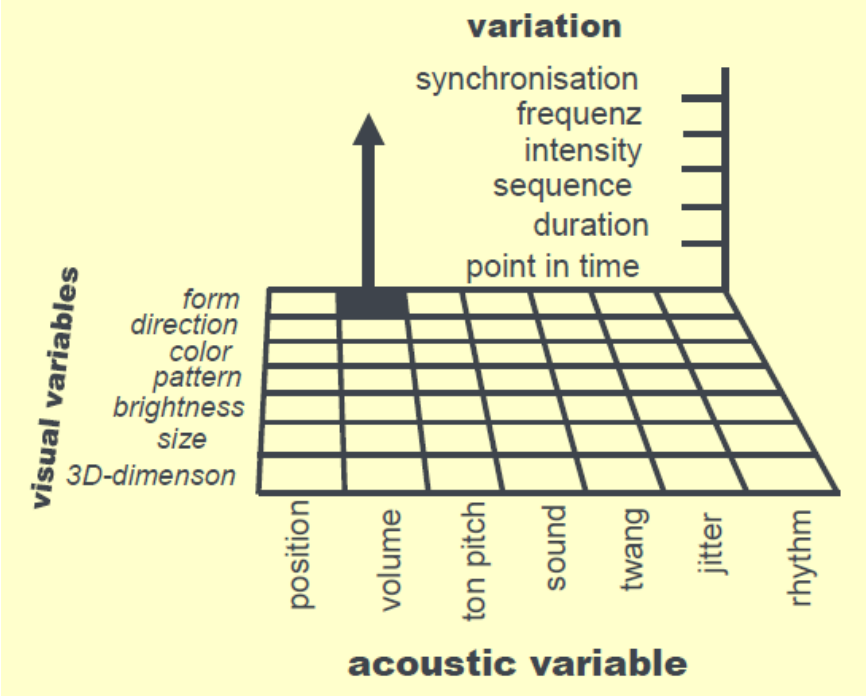
- Map title
- Legend
  - to figure out the information on the map: signs and symbols of all used points, line or areal signatures
  - to design the map: definition of the symbol, part of the editorial
  - not only abbreviation, also used as translation between cartographer and map user
  - demands on the legend
    - expalain about topic and statement of a map
      - clearly arranges, explict connection to the map
      - interconnected system

        - strcutured with hieracrical groups, e.g., in context of the feature classes
        - values are comparable to the values on the map
- North arrow or compass rose
- Map scale and scale bar
- Name of author and cartographer
- Indication of sources
- Publishing house(manufacture, editor or publisher)
- Printing press
- Year of production
- Map projection
- Copyright note
- Other texts

Cartographic animations & current trends in cartography

Cartographic animations

Basic of animations



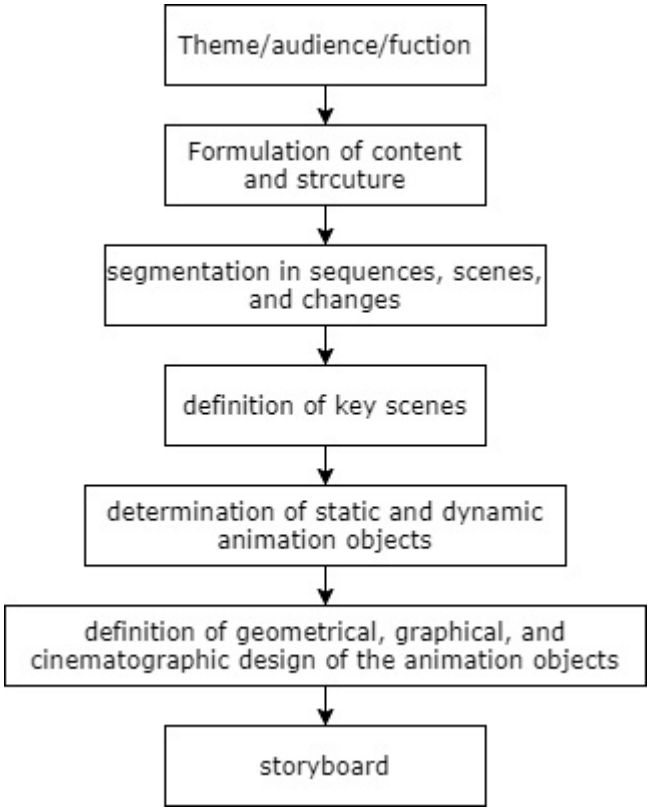
- variation
  - synchronization
  - frequency
  - intensity
  - sequence
  - duration
  - point in time
- acousic variable
  - position
  - volume
  - ton pitch
  - sound
  - swang
  - jitter
  - rhythm
- computer animation offers the opportunity, to leave the currently static and isolated forms of representation

- computer animation is a sequential presentation, i.e., only the factor time is new

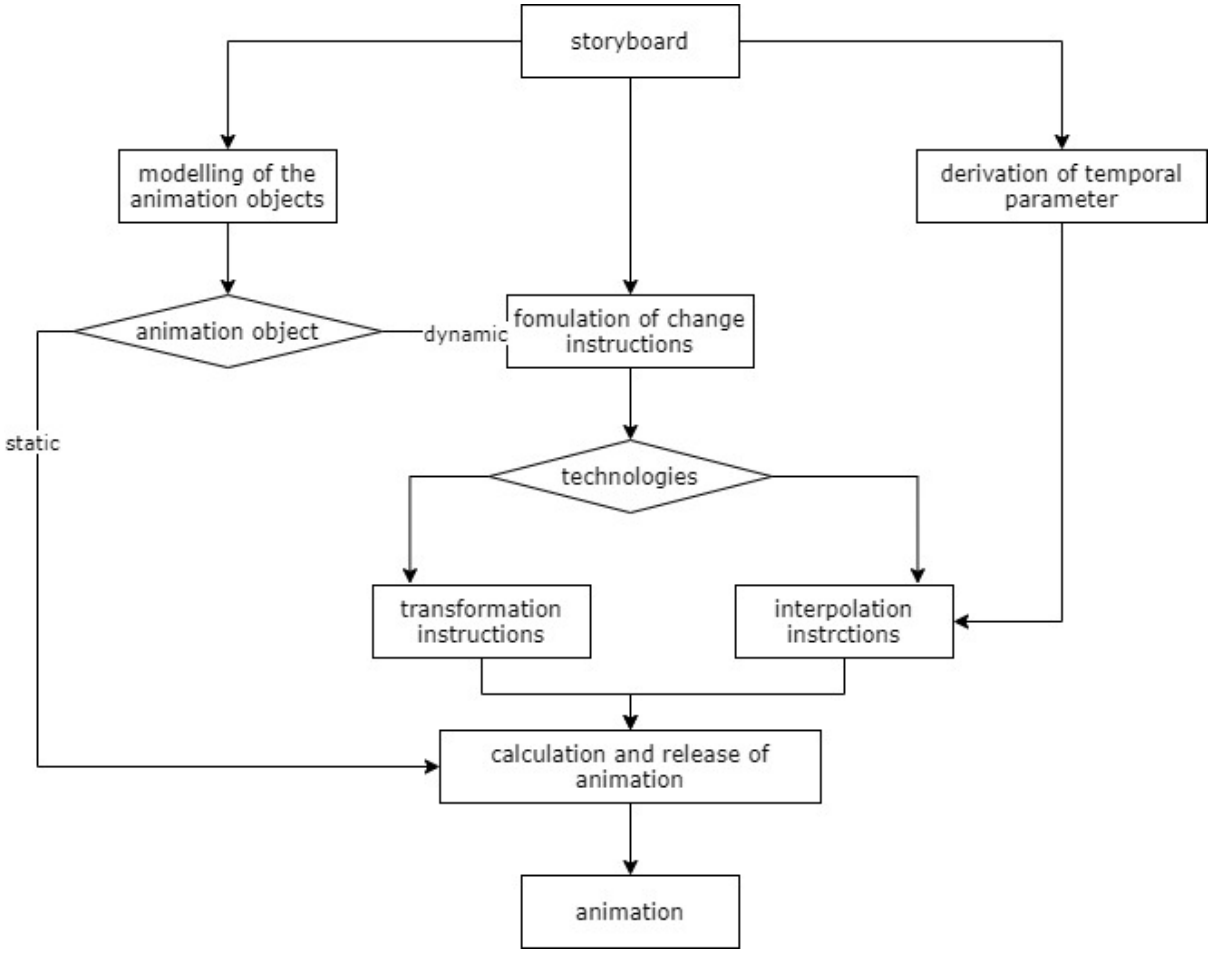
Components of animation

- animation objects(=basic animation objects)
  - graphic objects - information carrier
  - camera definition(point of observation, distance, angle) displayed map detail, scale and perspective
  - source of light
- scene(frames)
  - composition of animation objects to a overall picture
  - dedicated scenes - key frames
  - in-betweens are derived
- sequences
  - all scenes depending to a particular action, are combined to sequence
  - transitions connect the different sequences
- changes
  - time series
  - parameter changes in the data pre-processing(e.g., variation of classification)
  - parameter changes in the graphical presentation(e.g., change of point of view)
- sound audio or sound track
  - additional information medium
  - steering of perception and attention

The animation process: Design



The animation process: Realization



Classification of cartographic animations

- morphing animation
  - transfers starting form into final form
  - represent distortions of an area due to various map projection
- path animation
  - moving an object along a defined path
  - this path is committed on an own path level within the animation program
  - an animation is generated moving the animation object along this path
- camera animation
  - for 3d animation with variable camera adjustment and light sources
  - camera flight around the earth
- colour animation

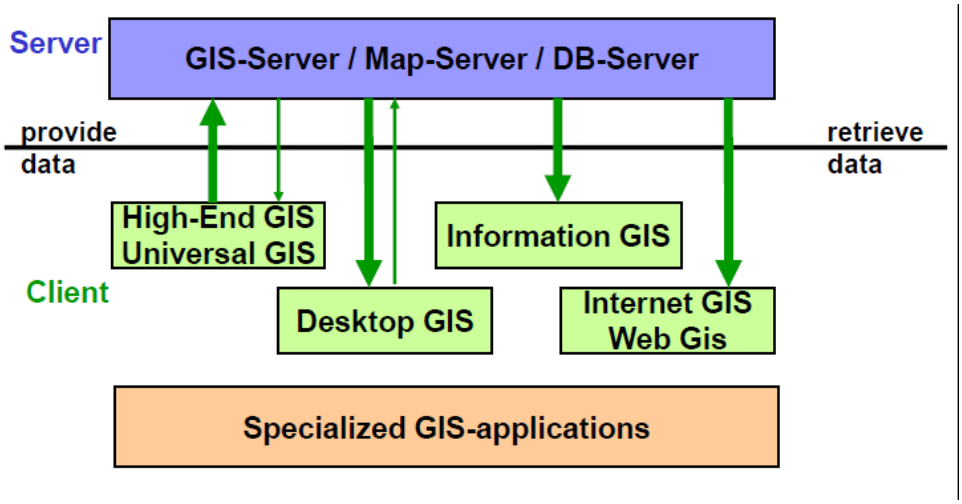
- produced directed colour waves
- representing continually flowing movements

- actors animations
  - leads animation objects according certain scripts on a determined background level

Current trends in cartography

Internet cartography

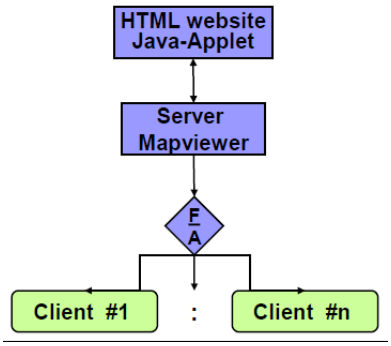
- intersection of the system classes



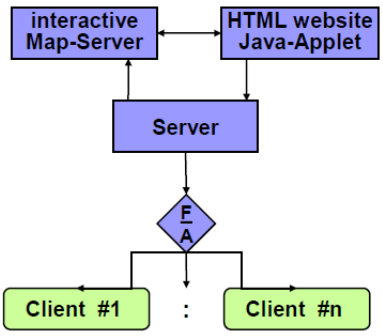
- client server communication
  - take the different functions of the various GIS into account
  - Server(database+middlewave) - url - browser(client)
- map server

Categorie	Functions			
	Capture & Store	Query	Analyze	Display & Output
Geodata-Server	+			
Map-Server	+			+
Online-Information System	+	+		+
Online-GIS	+	+	+	+
Function-Server		+	+	(+)

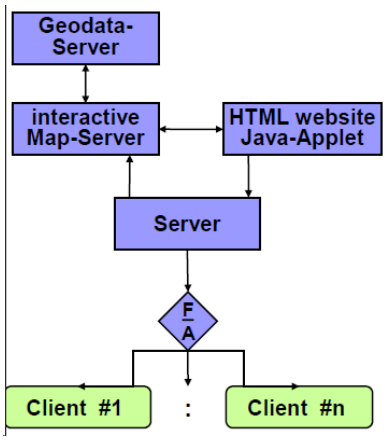
- static map server allows the visualization of spatial data via the Internet, clients can get prefabricated maps



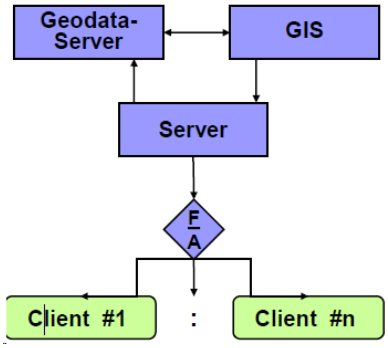
- interactive map servers allow users to have an impact on the visualization e.g. the coloring



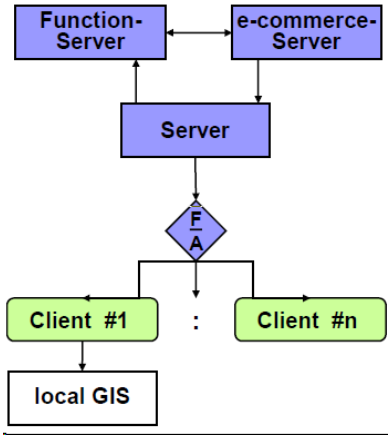
- online information system, map-based information retrieval systems allow access to static or interactive maps and furthermore first simple thematic or spatial queries



- online-GIS offers unlimited access to the data and function of a GIS



- function-server offers GIS function and algorithms as a web-service, results are visualized by the client, often combined with a e-commerce system



- geodata server/spatial data warehouse offers geographic data via the Internet

- products and technologies
  - GIS system: geomedia professional(Intergraph)
  - application server: geomedia webmap professional(Intergraph)
  - database management system(DBMS)
  - Web Server: Internet Information Server (Microsoft)
  - Programming/ scripting language: Active Server Pages/PHP/HTML
- current development of open geospatial consortium(OGC)
  - web map service(WMS): specification to publish spatial data as map
  - web feature service(WFS): de-facto standard for access of vertor-based spatial data

- geodata stored within a database or files
- harmonization of data access by definition of a standardized interface
- xml-based query

spatial data infrastructure: distributed data and services inside the internet

- worldwide: global spatial data infrastructure(GSDI)
- europe: INSPIRE
- germany: GDI
- federal states of germany

open street map

- collaborative project to create a free editable map of the world
- created by users worldwide

3D cartography

graphic representation of a part of the ground in a perceptively inclined view with topographical information about the ground

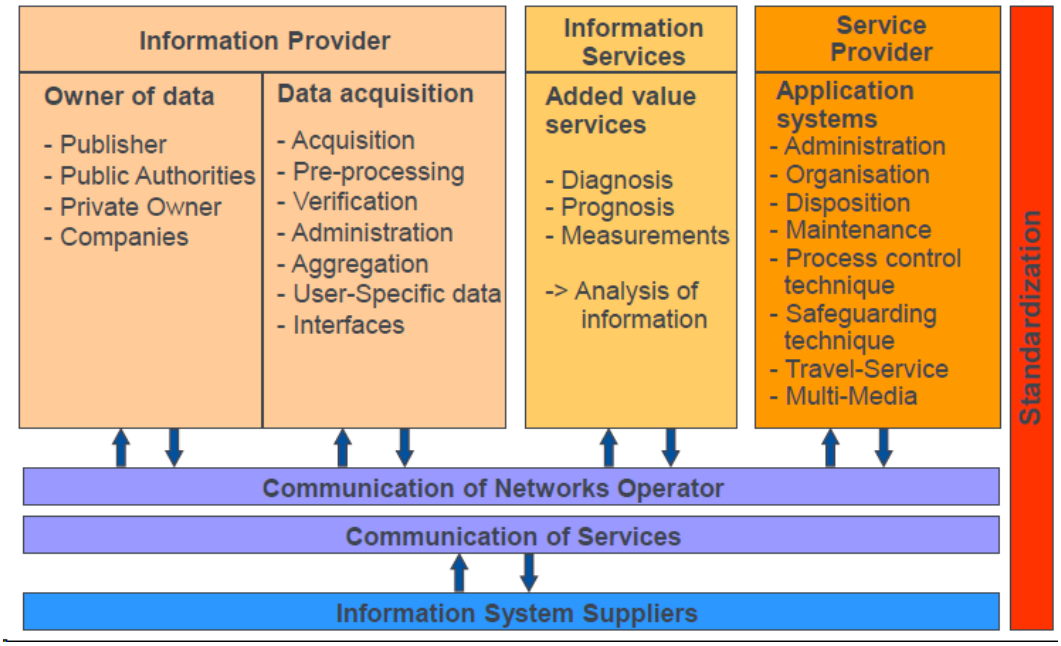
mobile cartography

- theories and technologies of dynamic cartographical visualization of spatial data and their inter-active use on mobile devices
- chanllege: get the data anywhere and any time
- small display and limited computing server: web server, readable information

dynamic cartography

Geodata market

Information chain

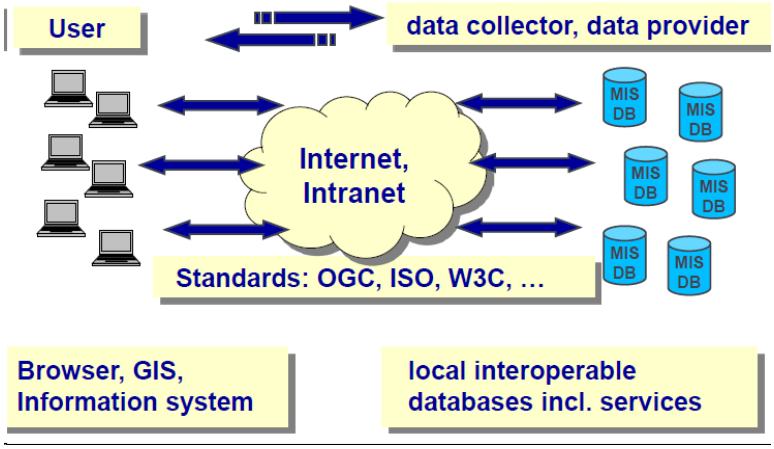


- introduction
  - buying and selling of information
  - add value by aggregation of information of different sources
  - providing diagnosis, prognosis, recommendation and information maintenance
- information survice provider
  - data proprietors(publishers, public authorities and private owners)
  - agensies acquiring data to acquire, pre-processing, verify, administer and aggregate information
- information services: analysis of existing information
  - buy base information
  - offer added value services
- service provider
  - actual purchaser of information and application systems
- communication network providers: owners and providers of these networks provide the communication infrastructure
- communication services: they pay for the usage of existing communication networks and offer own services to the customer

Standardization of spatial data

- data agencies, added-value services, and end-users are based on a standardized information structure with a common data model
- different parties agree on a specific catalogue of objects, a common information structure, a data model, and an exchange format
- motivation and basics
  - to simplify data exchange between different GIS systems
  - GIS standards
    - manufacture specific standards
      - shape files(ESRI)
      - DXF(AutoCAD exchange format)
      - SQD(SICAD)
    - user-specific standards
      - ATKIS(topographic data) in Germany
      - EDBS(data exchange for ATKIS/ALK) in Germany
      - DIGEST(digital information geographic exchange standard) within different NATO-countries
      - GDF(geographic data file) for road navigation
      - SDTA(spatial data transfer standard) in North America
- important standardization committees
  - ISO: international organization for standardization
    - develop and publish International Standards
  - DIN: Deutsches Institut für Normung(german standardization committee)
  - OGC: open geospatial consortium
    - non-profit, international, voluntary consensus standards organizations for geospatial and location based services
    - OGC takes over the ISO standards as abstract specifications and develops implementation specification

Spatial data infrastructure(SDI)



- spatial data infrastructure consists of regulations, technical and organizational aspects for spatial data resources
- components
  - spatial data and their meta data
  - services and standards
  - general political conditions, e.g., prices and availability
  - inter-organizational arrangements
- goal and purpose: simplification of data access and exchange
- conditions: cooperation and standardization
- initiatives to set up SDIs by public and private organizations on different levels: regional, national, european, global
- application
  - Regional planning, building industry
  - Environmental management and nature protection management
  - Internal security
  - National defense,
  - Civil defense and disaste control,
  - Supply and disposal,
  - Water management,

- Geoscientific resource protection,
- Agriculture and forestry,
- Meteorology, climatic research,
- Statistics,
- Insurance,
- Telematics / Traffic management

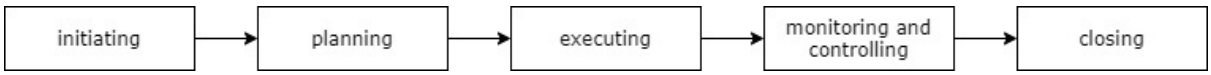
Metadata

- metadata is supporting descriptive information about data
- types of metadata
  - semantic metadata: define the functional meaning by a content-related description of the spatial data(units, etc.)
  - syntactic metadata: deliver the structural and formal description
  - pragmatic metadata: describe questions concerning usability, like access path or assignments concerning data protection

Copyright

Project management

Project management - general view



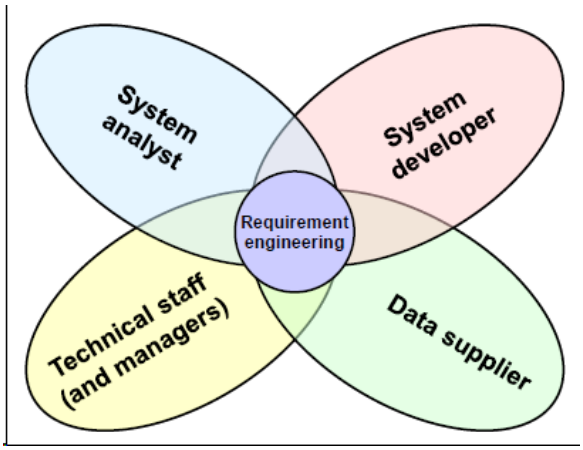
- managing a project typically includes
  - identifying requirements
  - addressing the various needs, concerns and expectations of the stakeholders as the project is planned and carried out
  - balancing the competing project constrains including but not limited to: scope, quality, schedule, budget, resources and risk
- the project management knowledge areas 9

- project **integration** management: to identify, define, combine, unify and coordinate the various processes and project management activities
- project **scope** management: to ensure that the project includes all the work required, and only the work required, to complete the project successfully
- project **time** management: to manage timely completion of the project
- project **cost** management: estimating, budgeting, and controlling costs so that the project can be completed within the approve budget
- project **quality** management: determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken
- project **human resource** management: organize, manage, and lead the project team
- project **communications** management: to ensure timely and appropriate generation, collection, distribution, storage, retrieval and ultimate disposition of project information
- project **risk** management: conducting risk management planning, identification, analysis, response planning and monitoring and control on a project
- project **procurement** management: to purchase or acquire products, services, or results needed from outside the project team

Requirement engineering

- motivation
  - customers' requirements on the system have to be documented completely, consistently and testable in written form
  - the customer requirement is a comprehensive description of the performance(e.g. technical, economical, organizational), necessary or demanded to reach objectives.
  - requirement analysis is basement of the development of information systems. Errors at this phase can often only be remedied with very high costs in the later course of the project
- capturing requirements

    - readable and traceable form
    - positive phrases
    - focus the requirements on the problem domain and the needs of the stakeholders
    - quantitative statements
- problems with the requirement engineering



    - stakeholders have divergent goals
    - conflict of interest between the parties
    - difficulties in the choice of priorities in conflicting requirements
    - unclear and changing organizational framework
    - constantly changing requirements
- success factors in determining the requirement
    - stability of the requirements of the project period
    - discipline in change management
    - the extent to which the project participants understand the objectives of the project
    - the extent to which the user/client are involved in the project
- Requirements modeling and specification
    - unified modeling language(UML)
        - UML - use case diagram

        - UML - classes diagram
        - UML - sequence diagram
    - function trees
        - general function - sub function
- content of a requirement engineering specification
    - objective
    - general description: environment, general function, restrictions, user
    - specific functional requirements
        - possible quantitative(e.g. table format)
        - clearly identifiable(numbers)
    - specific non-functional requirements: e.g. response time, memory requirement
    - design and product standards
    - quality destination
    - expected evolution of the system
    - crude identification of the versions

Data costs

- hardware
- software(operating system, GIS, database, text processing)
- personnel costs(basic salary, overhead)

Data quality

- Following quality characteristics have to be taken into account for quality description and evaluation of spatial data
    - dependability characteristics - describe the time related aspects of data quality
        - availability
        - up-to-datedness
    - integrity characteristics - describe the applicability of data

    - completeness
    - consistency
    - correctness
  - accuracy characteristic - describe the limitation of accuracy and resolution of measurement and interpretation
    - accuracy
- possible source of errors within gis analysis