ICA Tutorial on Generalisation & Multiple Representation

2 July 2011 Paris

Lecture 5 : Relation modelling and MRDB

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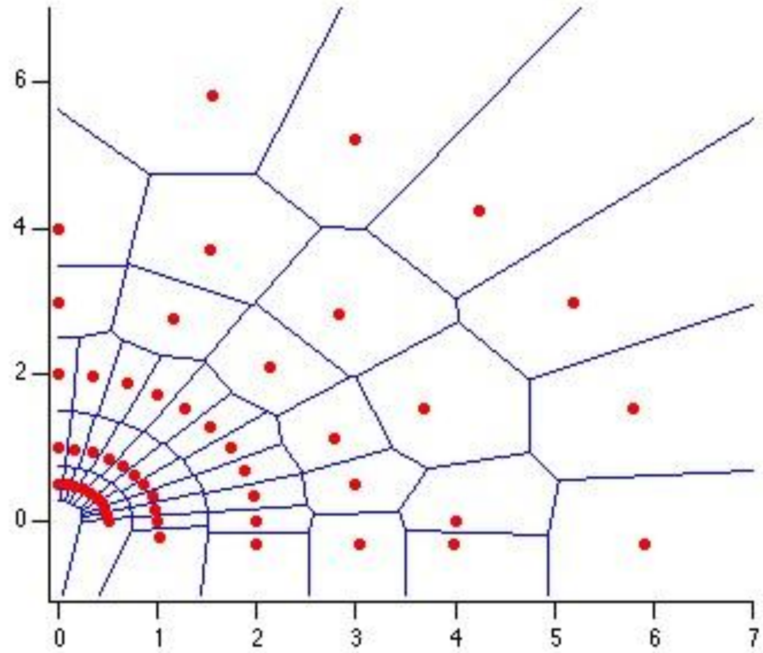
Outline

1. Triangulations
2. Reactive data structures
3. Relation modelling within MRDB
4. Literature



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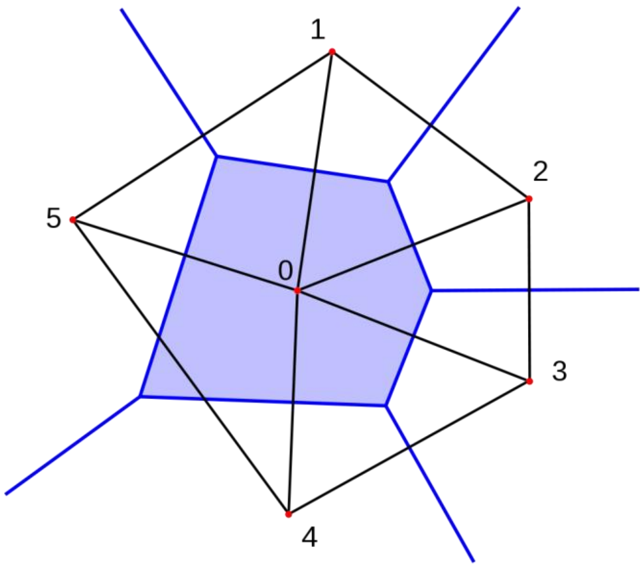
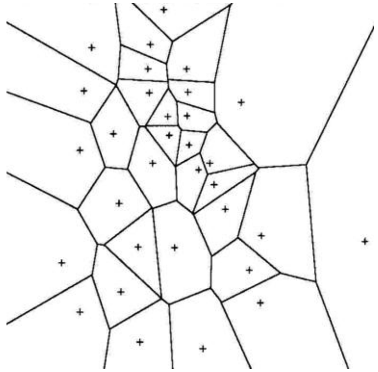
TRIANGULATIONS

Voronoi diagram

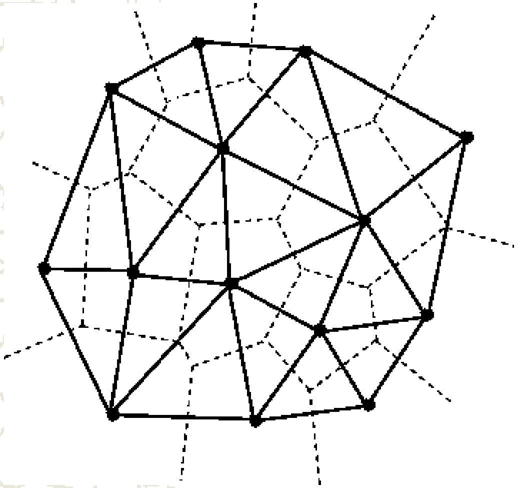
- Voronoi polygon - a polygon whose interior consists of all points in the plane which are closer to a particular lattice point than to any other
- all Voronoi polygons of a point set build the Voronoi diagram
- construction:
  - from the bisectors of adjacent points
  - each vertex of the Voronoi diagram is obtained as the intersection of exactly three bisectors
- alternative names
  - Thiessen polygons or Dirichlet tessellation



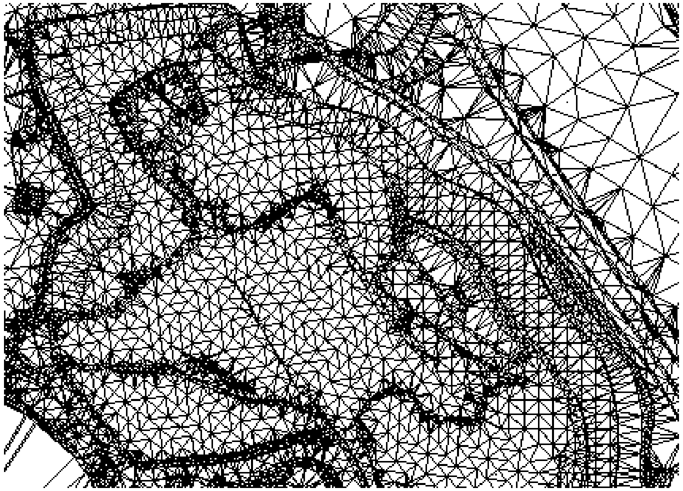


Delaunay triangulation

- the Delaunay triangulation (DT) refers to a network of several points on a triangle mesh
- the Delaunay triangulation is the dual structure of the Voronoi diagram
  - within the DT two points will be connected in case the corresponding Voronoi polygons have a common line



Delaunay Triangulation



TIN (Triangulated Irregular Network)

Delaunay triangulation

- selected properties
  - DT satisfies the circle criterion - no point is inside the circumcircle of any triangle
  - maximize the minimum angle of all the angles of the triangles in the triangulation
  - any other triangulation generates at least one triangle with an sharp angle

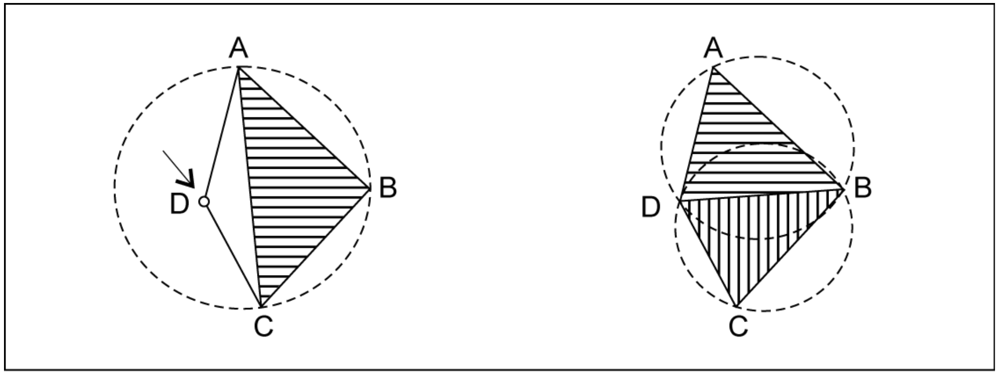
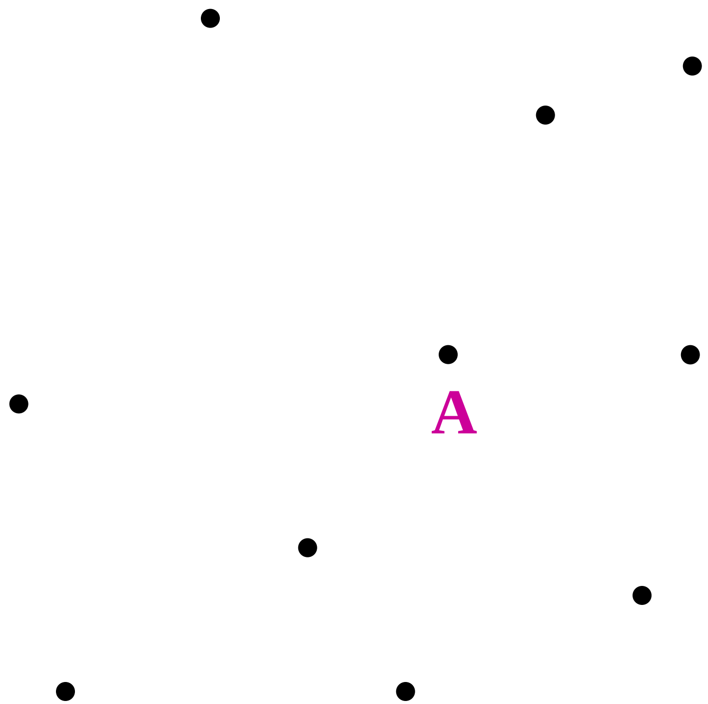


Figure left: the circle criterion is not considered, because point D is situated within the circumcircle of triangle (ΔABC)

Figure right: the triangles (Δ ABD, Δ BCD) satisfy the circle criterion → Delaunay triangulation

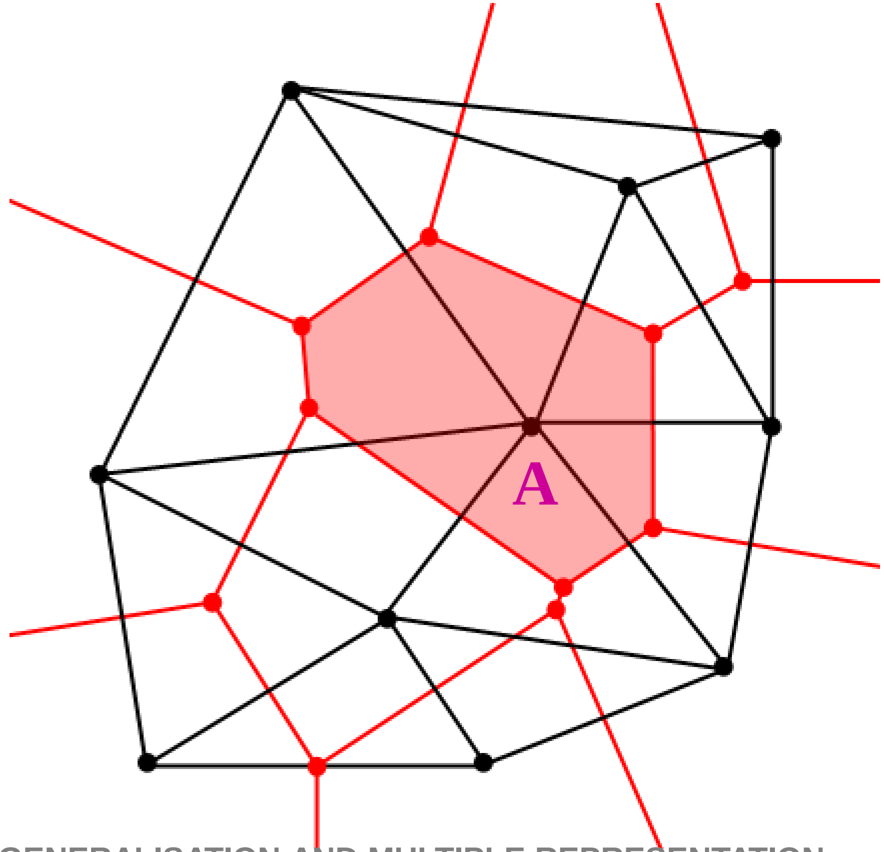
Task

construct Delaunay triangulation for the following set of points and the Voronoi polygon around point A



Task

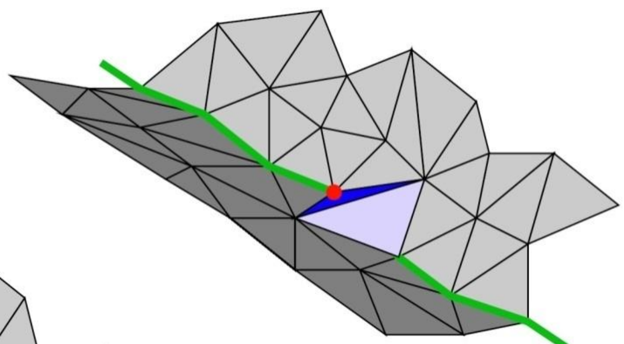
construct Delaunay triangulation for the following set of points and the Voronoi polygon around point A

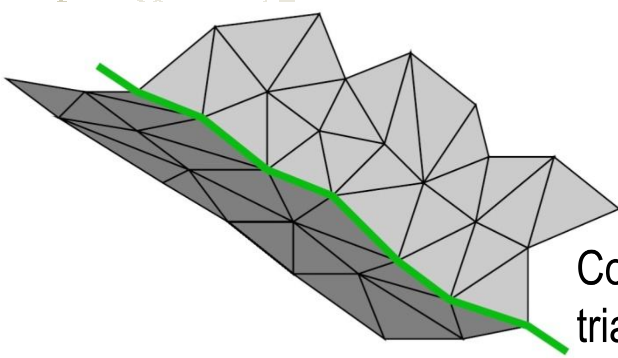


Constraint Delaunay triangulation

- triangulation is carried out not only on a set of points, but also on pre-defined edges
- applications
  - in digital terrain models (e.g. terrain edges or roads)
  - building generalisation

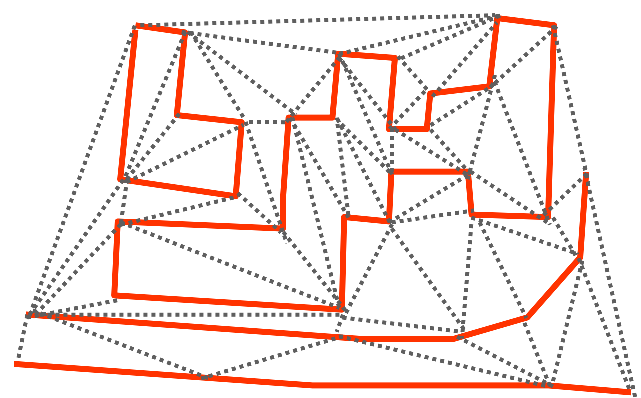
Delaunay triangulation with local minima



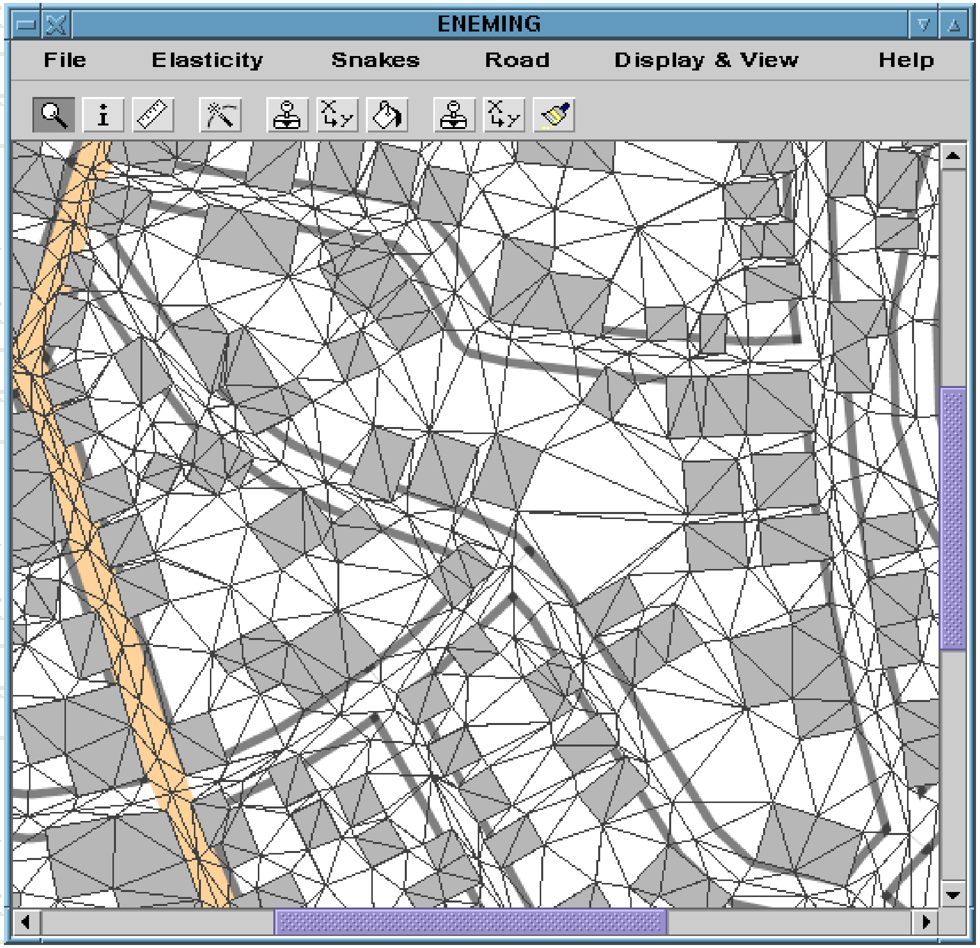


Constraint Delaunay triangulation

Constraint Delaunay triangulation with consideration of building edges

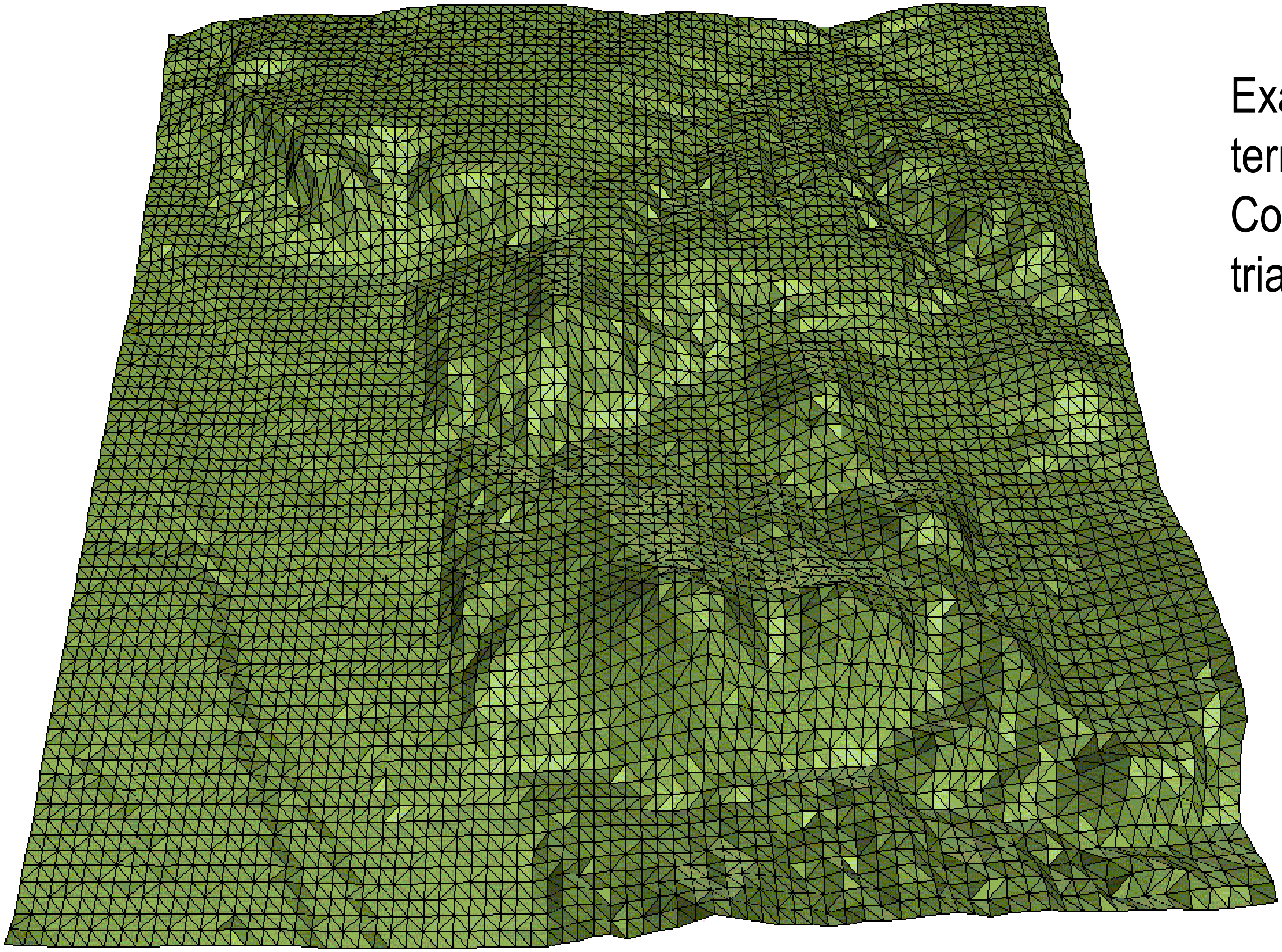


Constraint Delaunay triangulation



Bader, 2001

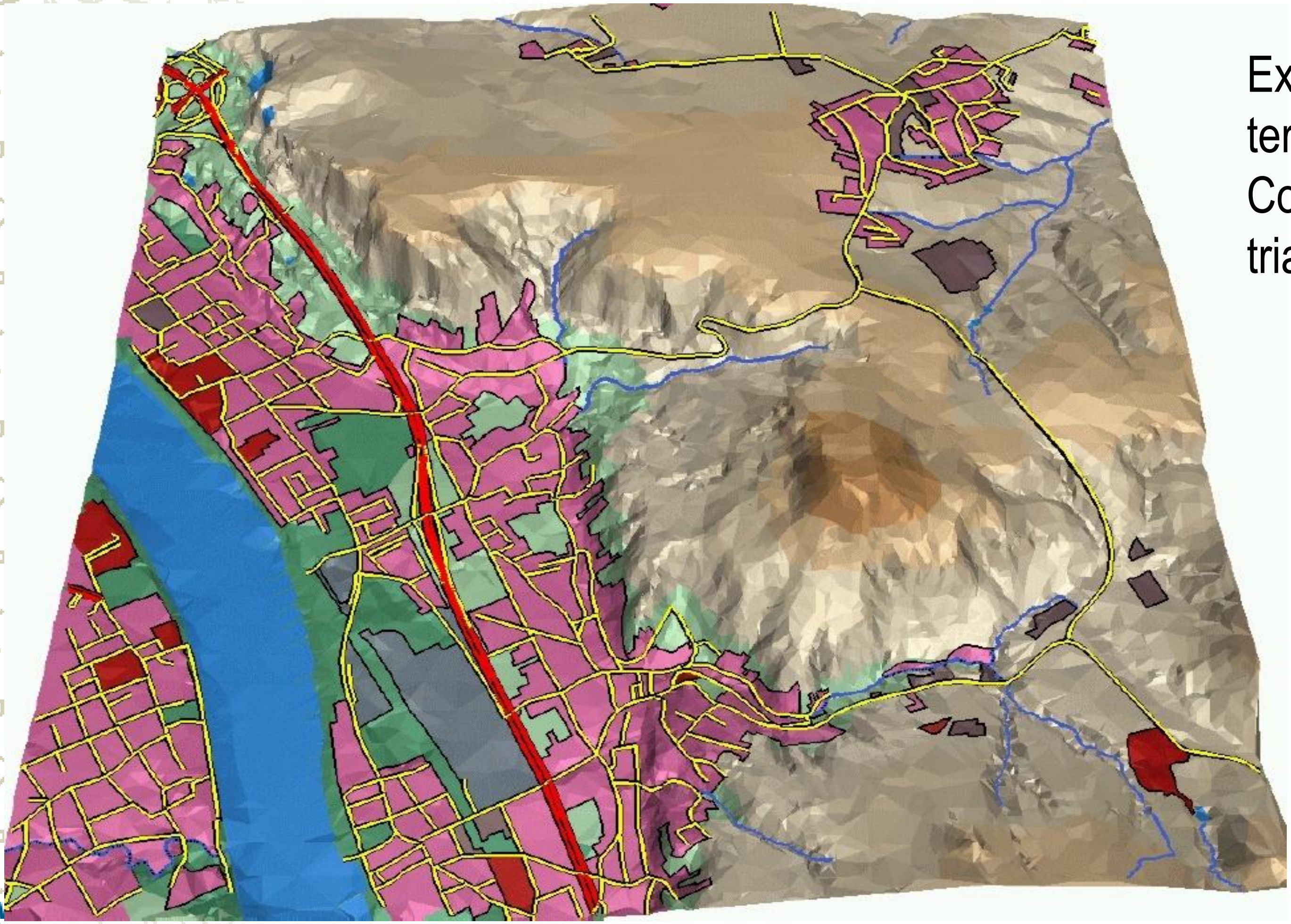
Constraint Delaunay triangulation



Example of digital terrain model with Constrained Delaunay triangulation

Source:
Institute for Geodesy and Geoinformation, University Bonn

Constraint Delaunay triangulation



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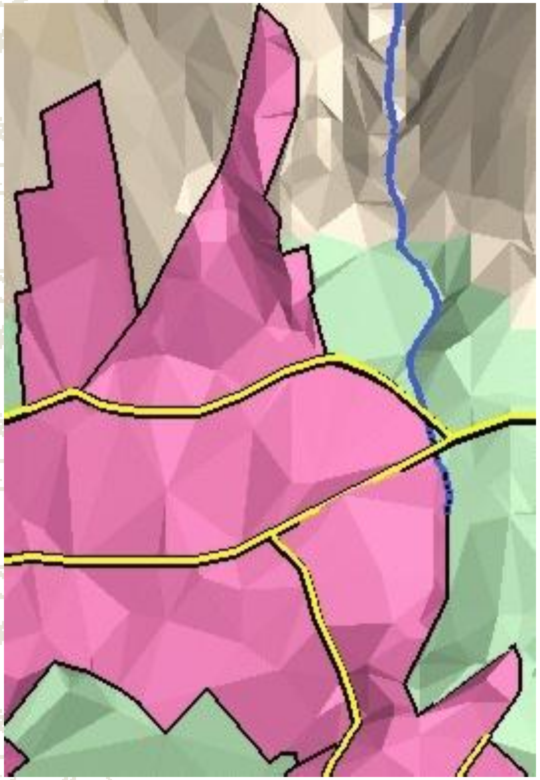
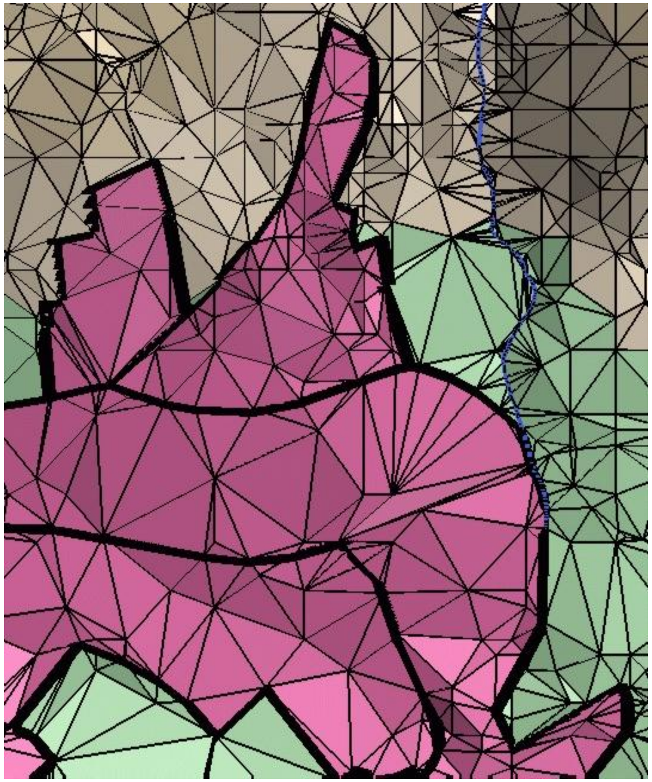
Constraint Delaunay triangulation

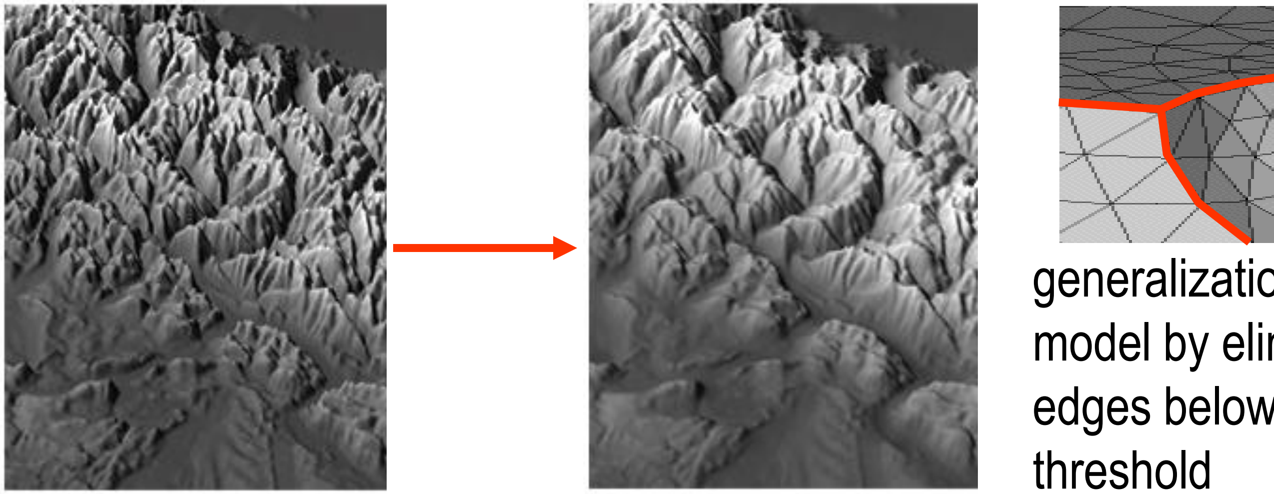


textured terrain model

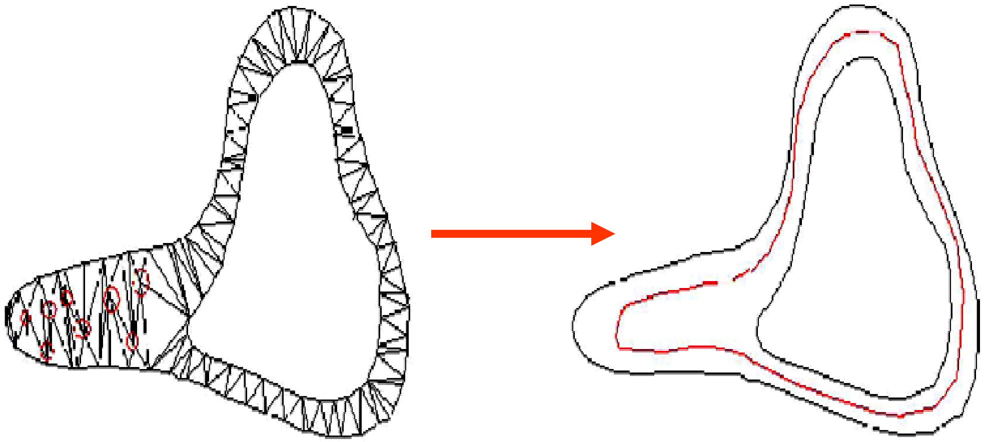


Constraint Delaunay triangulation with consideration of road axes

Applications of Voronoi, DT and CDT



generalization of terrain model by eliminating triangle edges below a sharpness threshold

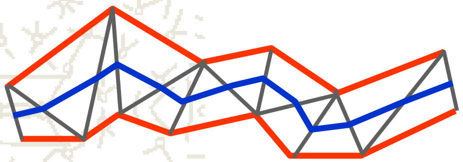


derivation of a new contour line based on CDT of existing contour lines and terrain points

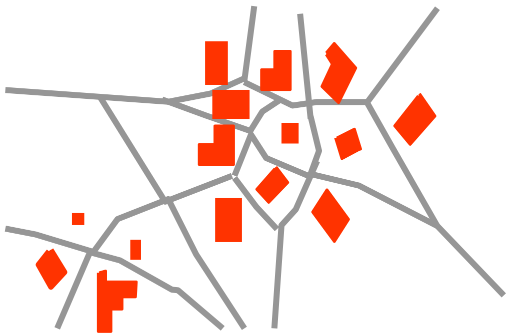
(Li et al. 1999)

Further applications of Voronoi, DT and CDT

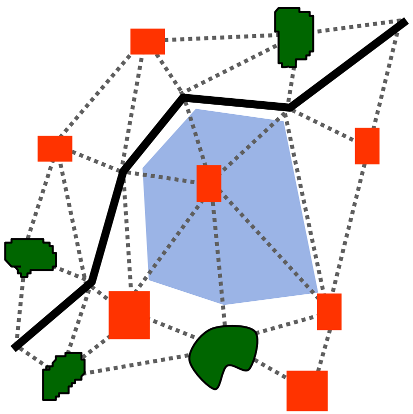
- extraction of middle axes (skeleton) of polygons or linear objects
- cluster detection
- determining neighbouring objects (non-metric) by searching through related triangles



middle axes

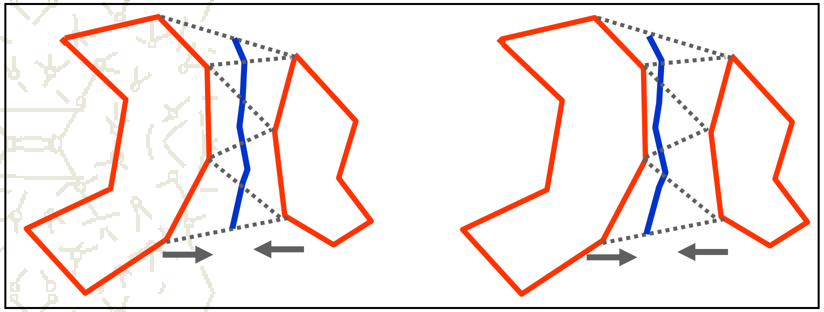


clustering



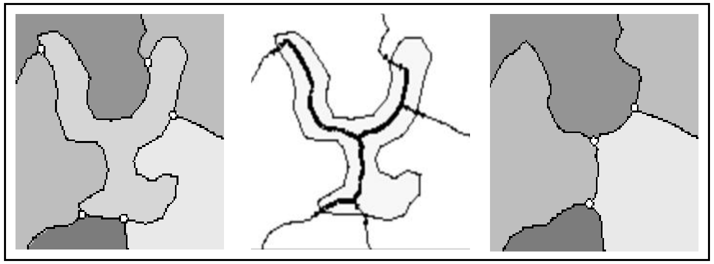
neighbourhood / near

Applications of Voronoi, DT and CDT

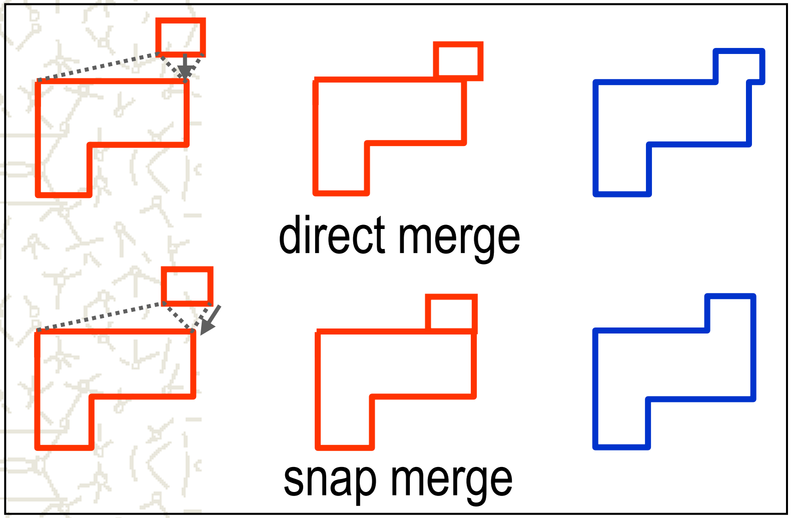


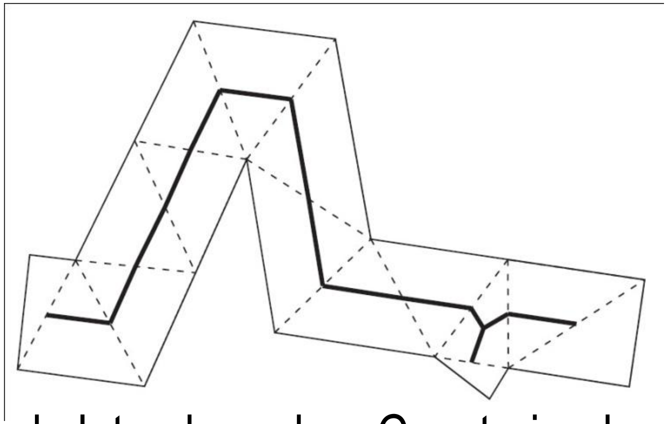
middle axis and weighted middle axis as merging boundary (Jones et al. 1995)

(Bader & Weibel, 1997)



new allocation of eroded area





skeleton based on Constrained Delaunay triangulation (Haunert & Sester, 2008)

REACTIVE DATA STRUCTURES

- BLG-tree: Binary Line Generalization (Oosterom, 1991)
- tGAP-tree: topological Generalized Area (Oosterom, 2005)
- reactive conflict graph (Petzold, 2003)

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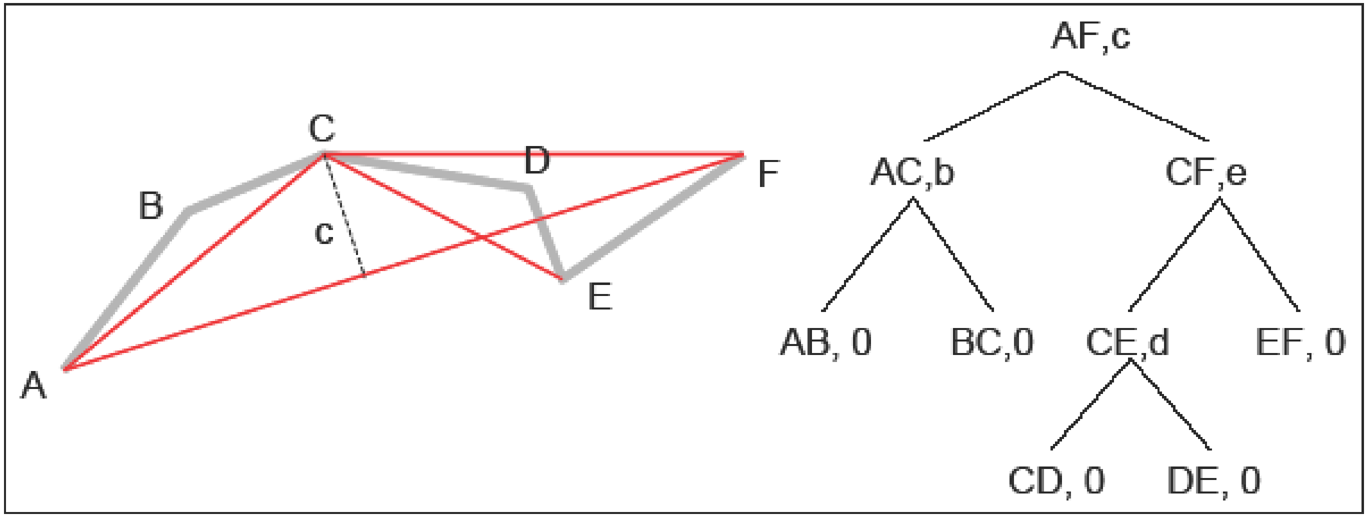
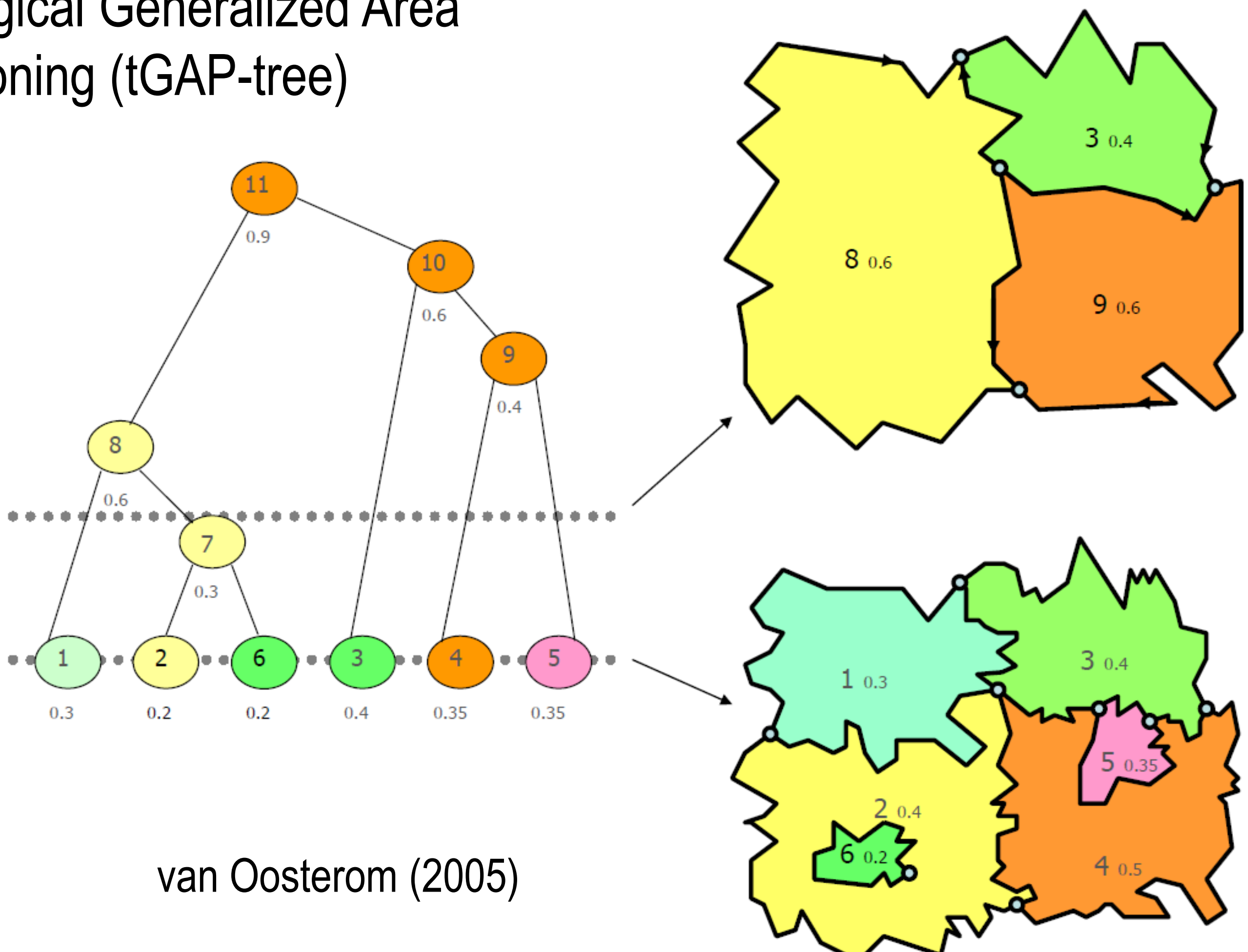
Binary Line Generalization (BLG-tree)

- BLG-tree (Oosterom, 1991) based on Douglas-Peucker algorithm for line simplification
- the use of hierarchical data structure allows the scale-dependent representation of linear objects with varying degrees of detail in real time (on-the-fly)



topological Generalized Area Partitioning

- topological Generalized Area Partitioning (tGAP-tree)

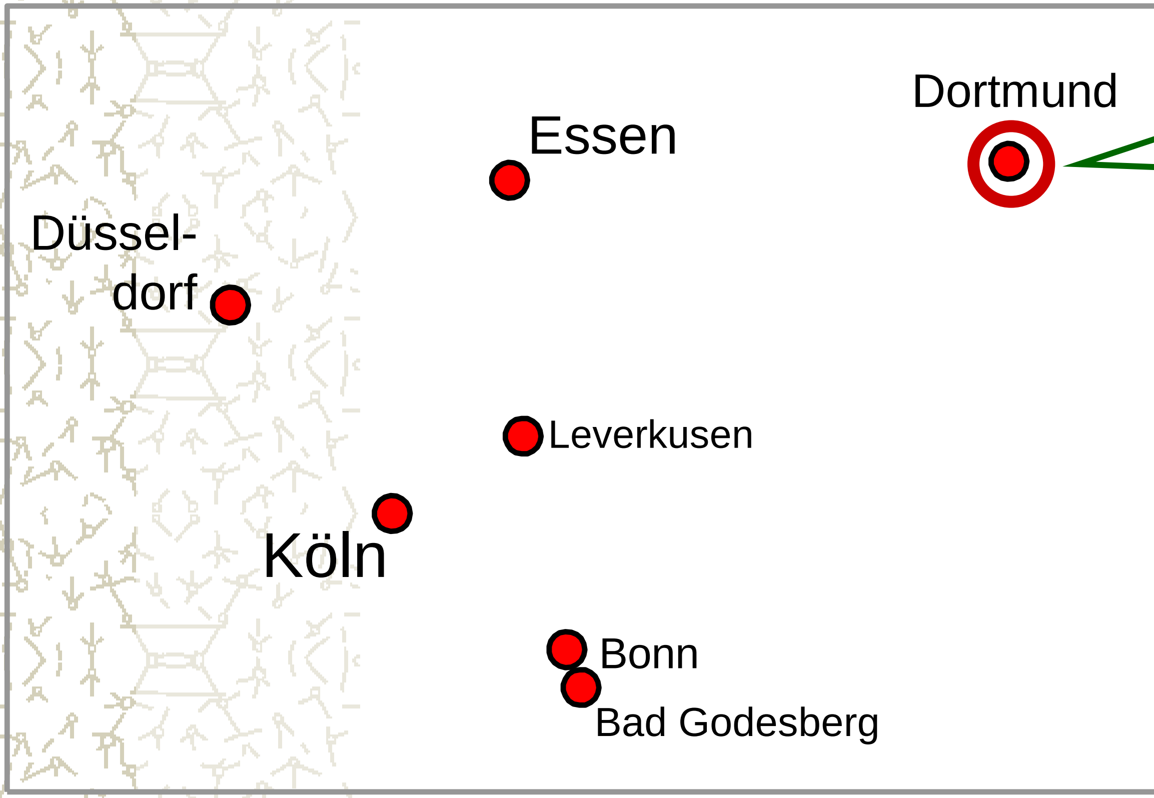


van Oosterom (2005)

Reactive conflict graph

- data structure for the storage of potential conflicts during automated label placement (Petzold, 2003)
- structure:
  - **nodes** ⇔ labelled **objects**
  - **edges** ⇔ potential **conflicts**
- potential conflicts are scale dependent
  - scale interval [lower boundary, upper boundary]
- 2 phases
  - pre-processing: creation of reactive conflict graph
  - interaction phase: usage of data structure

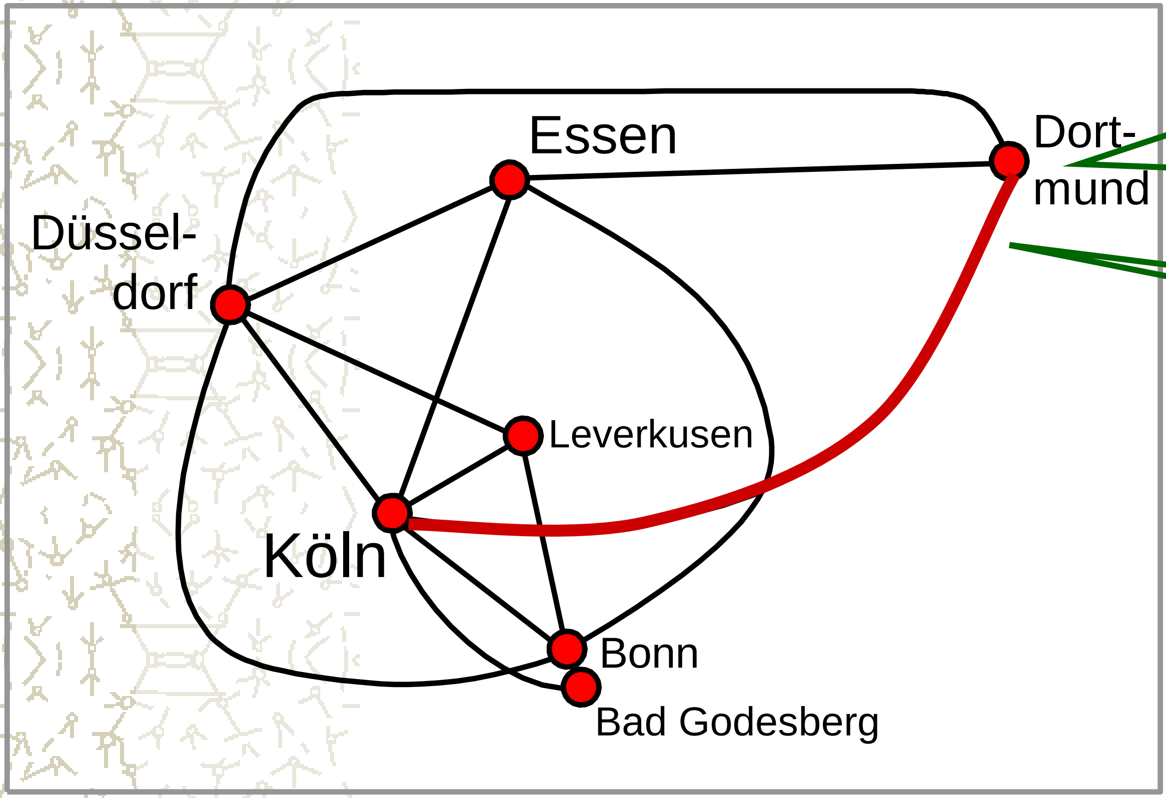
Reactive conflict graph: example



nodes
object to be labelled

Source: Petzold (2003)

Reactive conflict graph: example

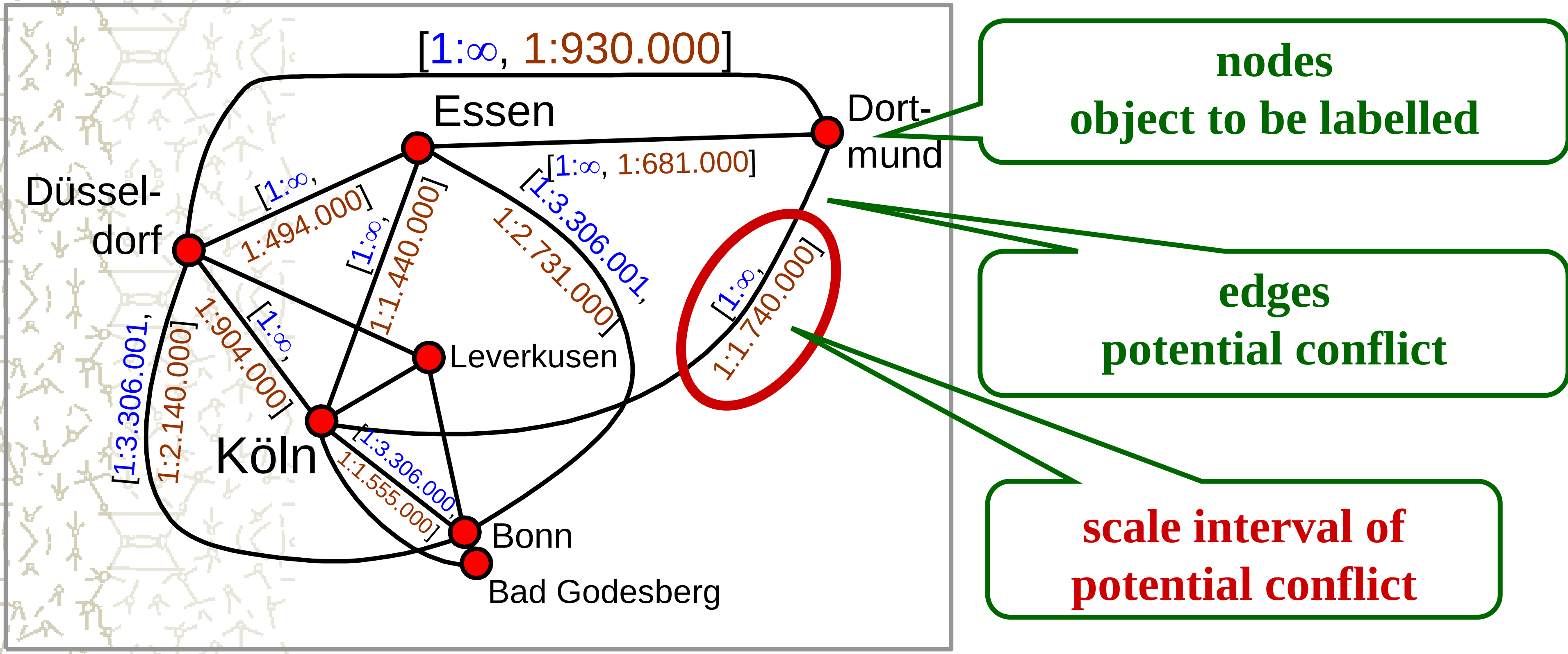


nodes
object to be labelled

edges
potential conflict

Source: Petzold (2003)

Reactive conflict graph: example

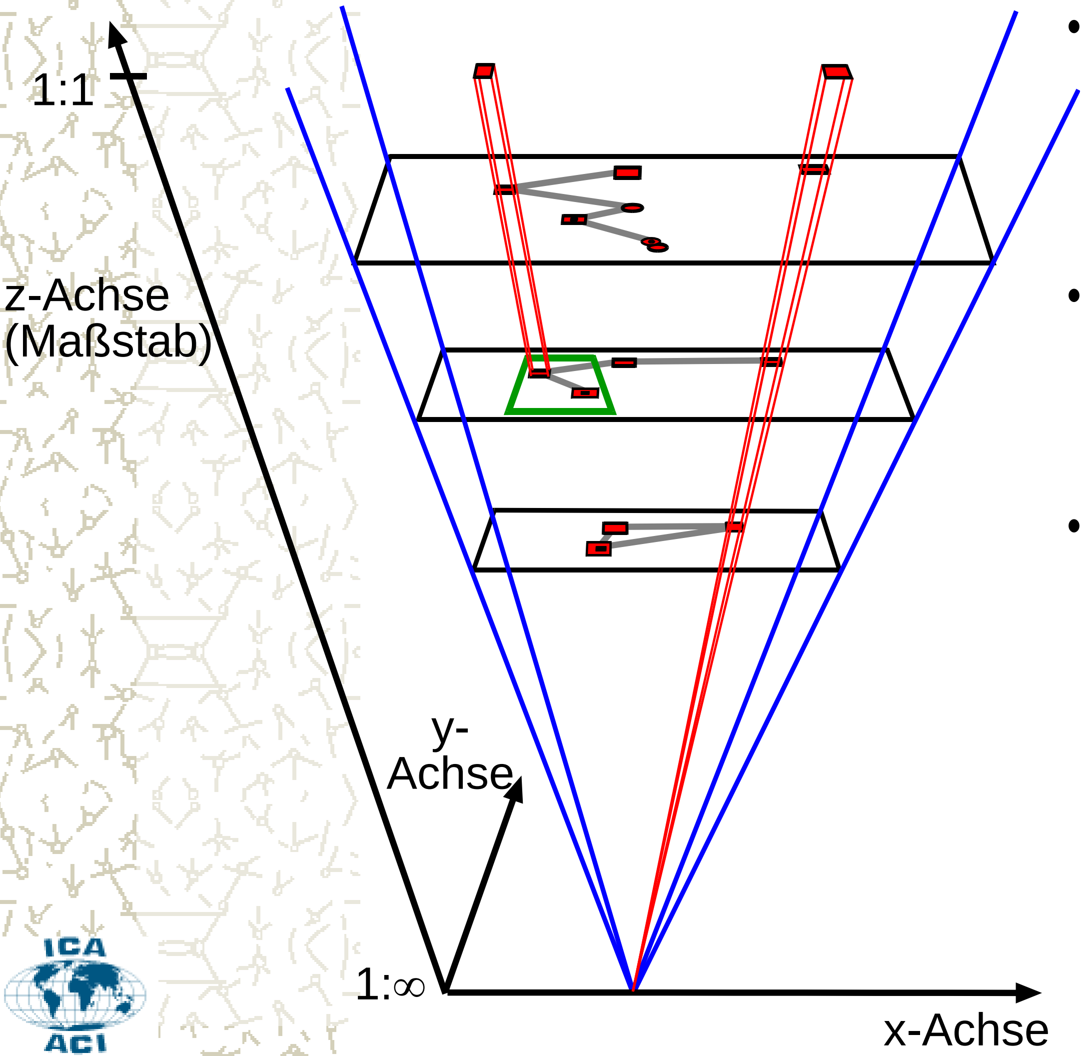


Bonn - Leverkusen	[1:1.307.001, 1:1.262.000]
Bonn - Bad Godesberg	[1:2.247.001, 1:100.000]
Köln - Leverkusen	[1:1.307.001, 1:274.000]
Köln - Bad Godesberg	[1:2.247.001, 1:681.000]

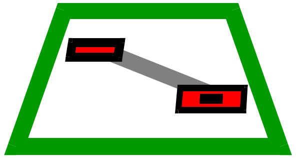
[1:987.654, **deselection scale** lower boundary

1:123.456] **overlapping scale** upper boundary

Reactive conflict graph: example



- 3 dimensions:
  - two spatial dimensions
  - third dimension (z-axis): scale
- request:
  - map extent
  - scale
- result:
  - static conflict graph adapted on scale



RELATION MODELLING WITHIN MRDB

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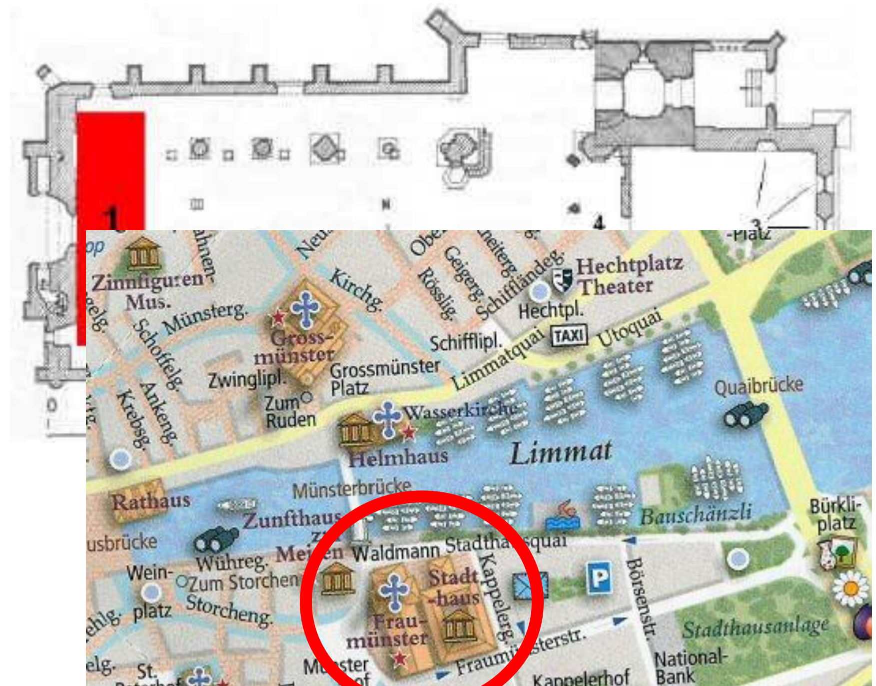
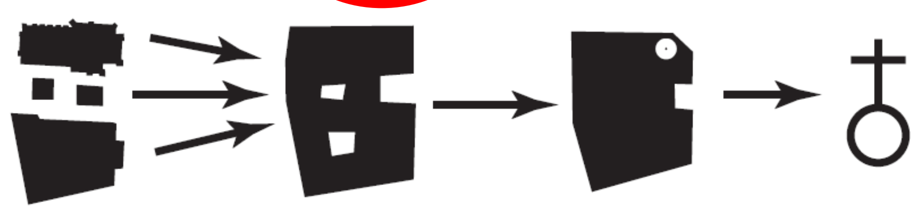
Relation modelling within MRDB





1 : 5000 1 : 25'000 1 : 50'000 1 : 100'000

Multiple representation

Why does different representation exist respective redundant storage of data?

- no information about the existence of already collected data
- different requirements of application, both in terms of semantic and technical aspects
  - phenomena can be described as an independent objects or through attributes as part of higher class objects (e.g. railway with 3 tracks)
  - information can be coded differently (different coordinate systems)
  - modelling differences (e.g. river can be modelled as area object or as line object; city as polygon or point, …)

Multiple representation database

Definition Multiple Representation Databases

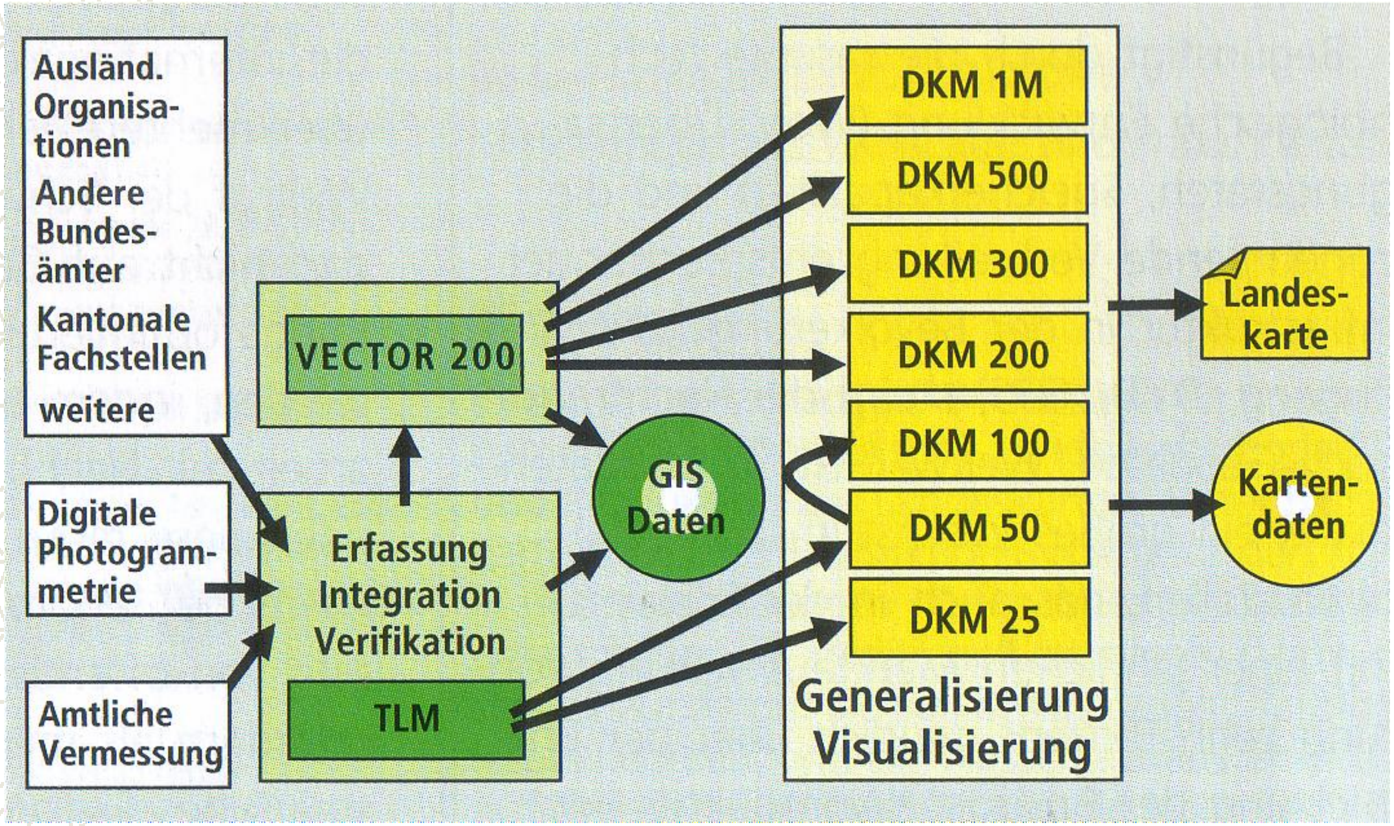
The term „multiple representation database“ refers to a database structure in which several representation of the same geographic entity or phenomenon, … are stored as different objects in database and linked. (Sarjakoski, 2007)

Advantages and usage of a MRDB

- supports effective data management, avoids storage of duplicated data sets
- quality checks and quality improvement of data sets (consistency)
- basis for automated, incremental updates
- supports spatial analysis
- extended usage scenarios in digital and mobile cartography (e.g. adaptive zooming)

MRDB in cartography

- at the NMAs different representation are related to traditional map series

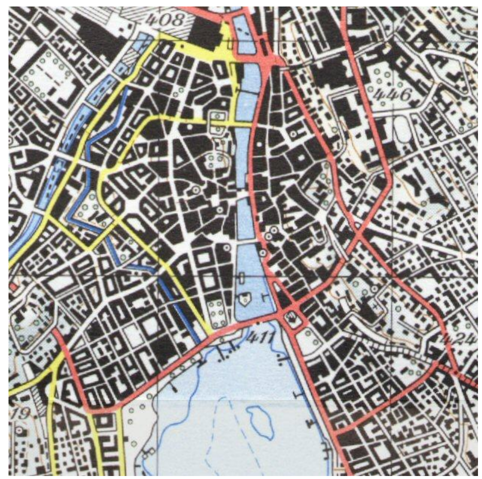


Source: Feldmann and Kreiter (2006)

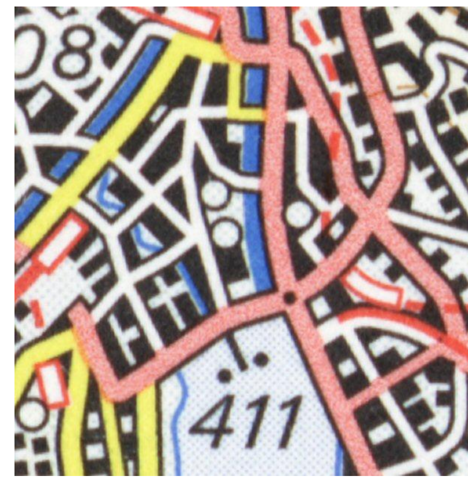
MRDB in cartography

- at the NMAs different representation are related to traditional map series

1:25‘000



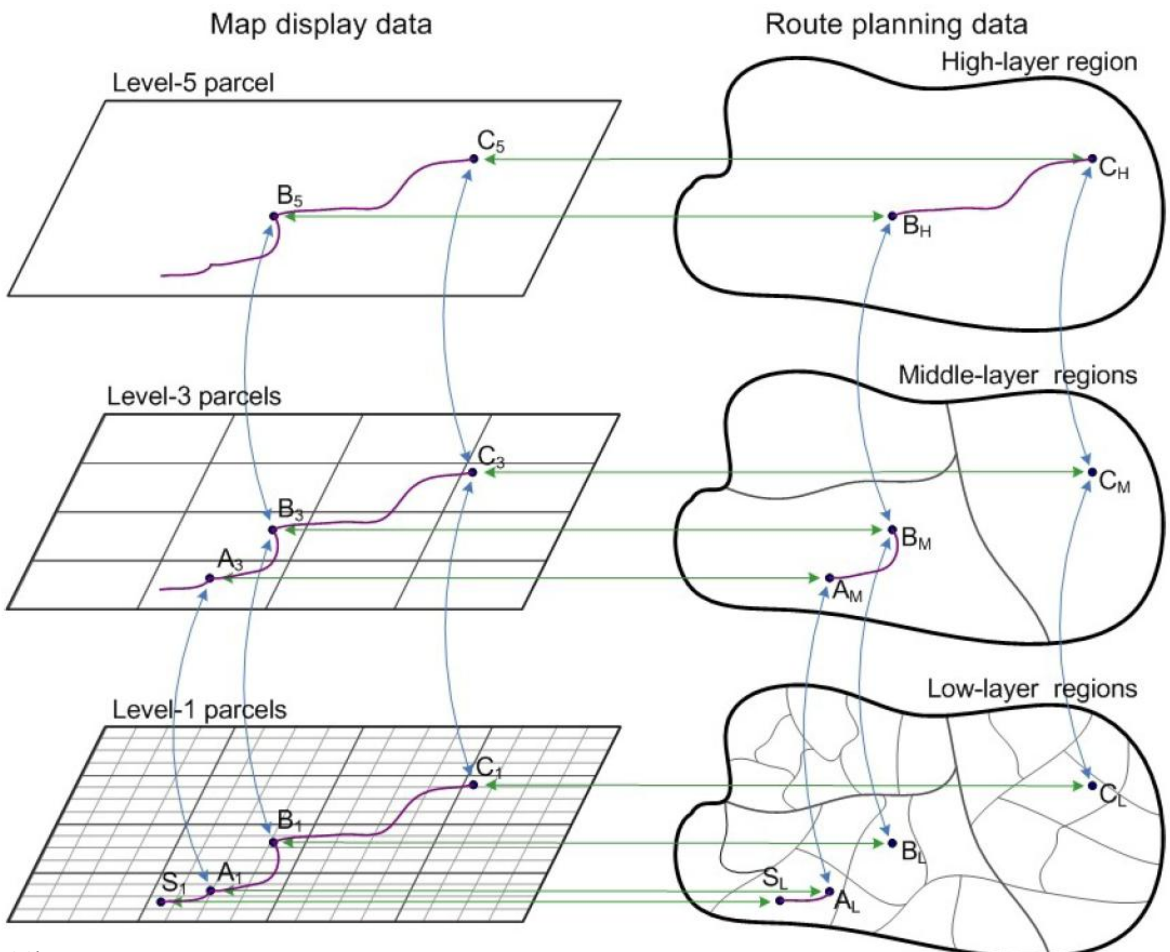
1:50‘000



1:200‘000

Source: Landeskarte der Schweiz, swisstopo

MRDB in car navigation



GONG, H. (2011),
Generalization of Road Network for Embedded Car Navigation System, PhD thesis, University Munich

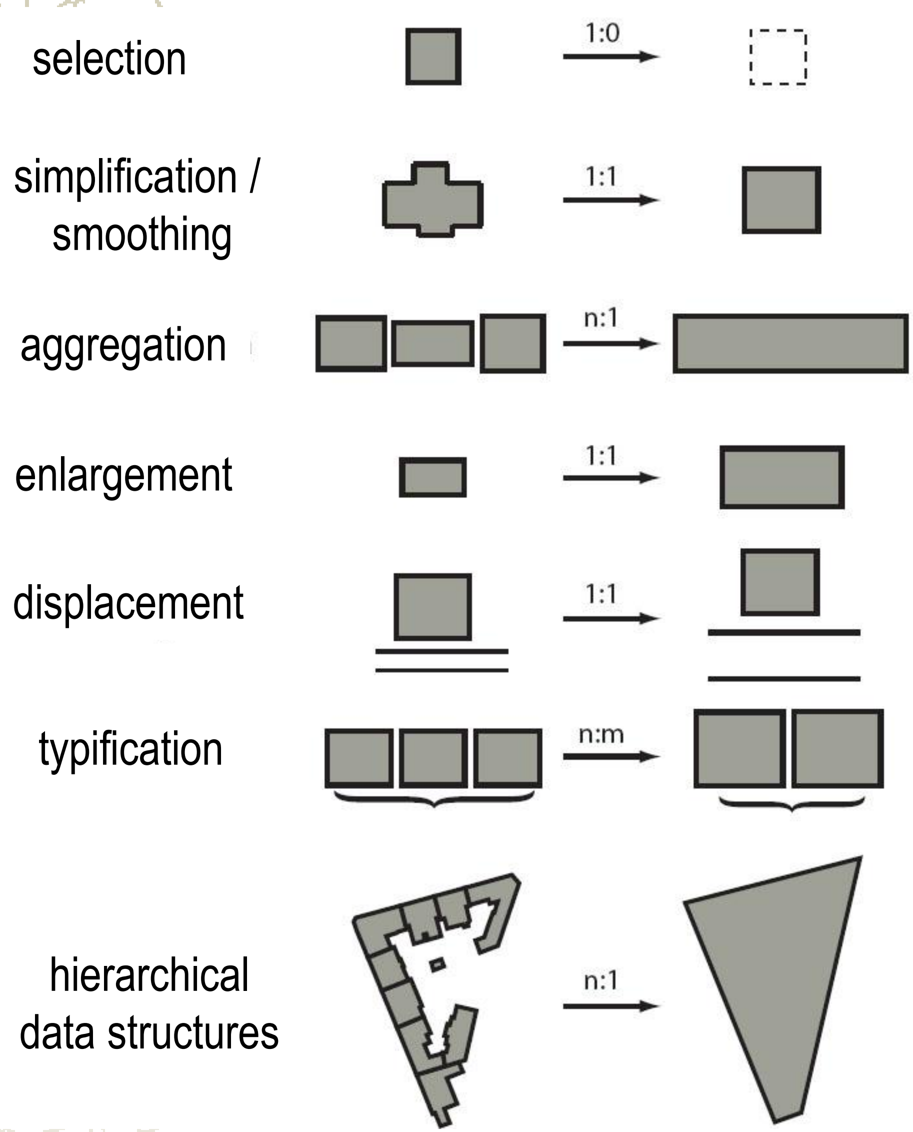
Relation modelling within MRDB

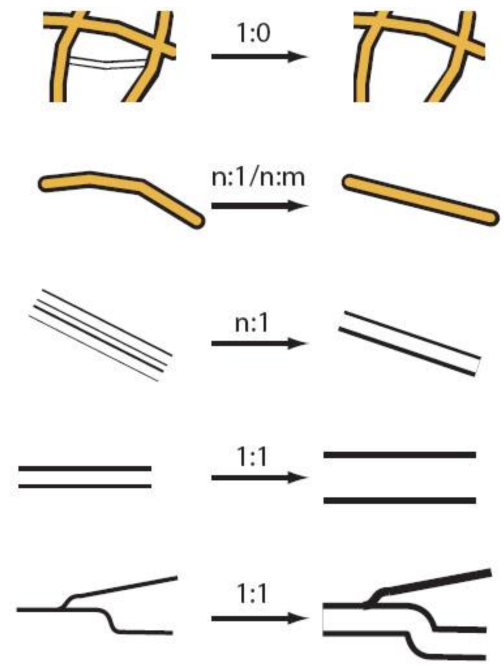
- type of relations modelled within MRDB is still an ongoing research topic
- current approaches distinguish three types of relations:
  1. vertical relations
  2. horizontal relations
  3. temporal / update relations

Vertical relations

- Definition - Vertical relations (VR) connect objects, which represent the same real world phenomena at different resolutions or Level of Detail (LoD) on a defined time stamp
- taking the assumption, that details and objects will be preserved or removed at smaller scales → a modelling of 1:1, n:1 and 1:0 relations would be sufficient
  - in the simplest case a connection through primary key and foreign key could be realised without introducing an explicit relation
- working with real data shows, that it is necessary also to model n:m-relations
  - thus explicit modelling of vertical relations as concrete instances becomes essential
- useful extension
  - additional meta information about applied generalisation operators can be stored as attributes of the vertical relations

Vertical relations

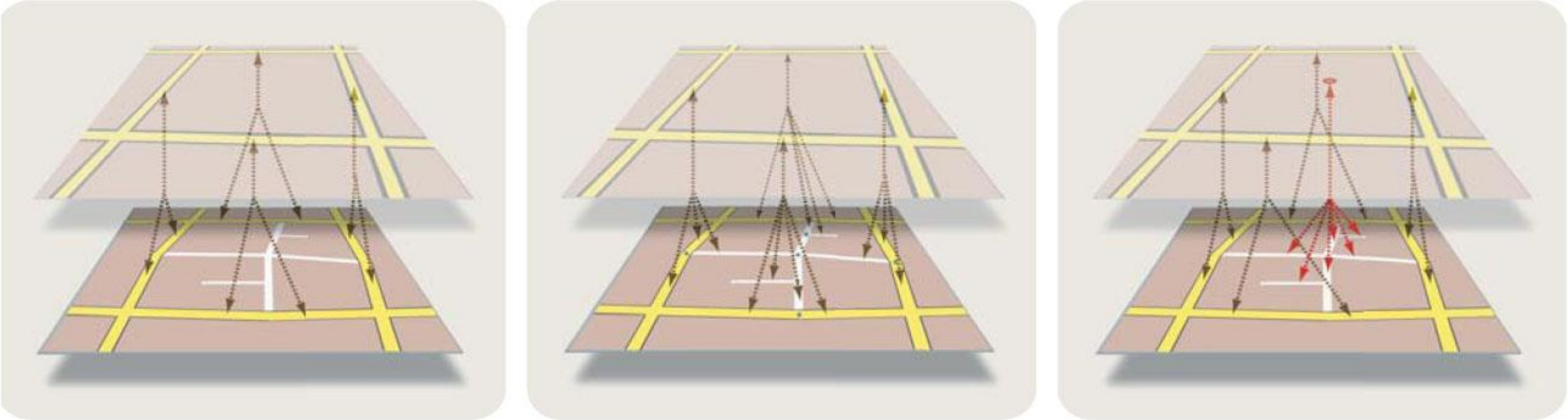




Source:
HAMPE, M. (2007),
Integration einer multiskaligen Datenbank
in eine Webservice-Architektur,
PhD thesis, University Hannover

Vertical relations

options for linking remove objects between different level of detail (LOD)



no linkages

alternative to Hampe (2007)
1:0 vertical relation

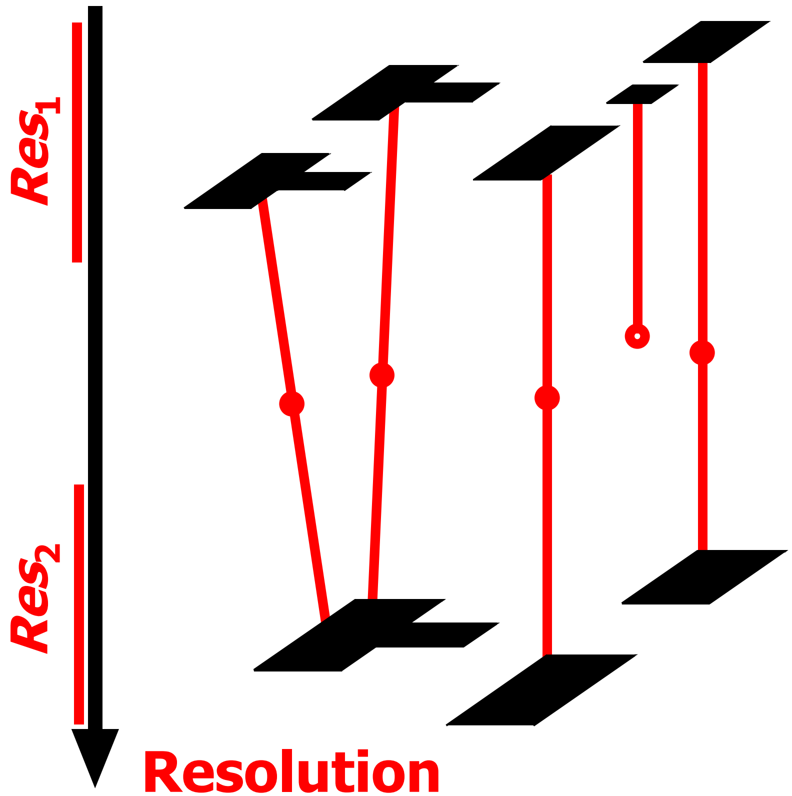
connection with neighbouring object of the same object class
(e.g. outgoing side street)

connection with object they go up
(e.g. outgoing street to settlement area)

Source: HAMPE, M. (2007), Integration einer multiskaligen Datenbank in eine Webservice-Architektur, PhD thesis, University Hannover

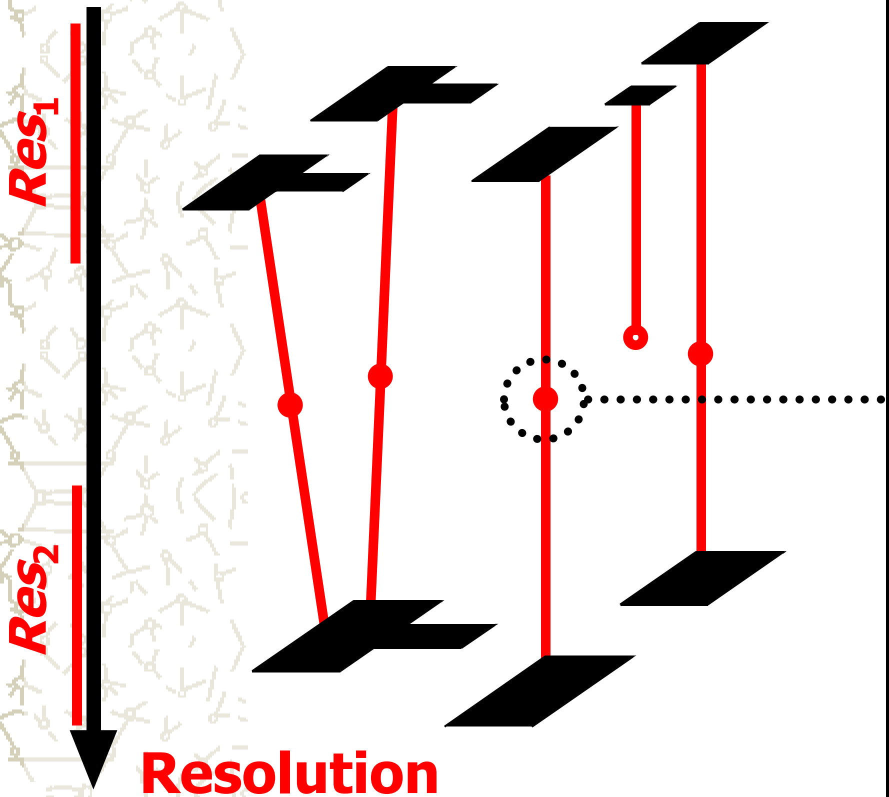
Characteristics

- an essential part of MRDB
- store meta-information of generalisation operators and parameters
- support automated update
- improves data quality by comparing consistency
- provides analysis functionality across all resolutions



Vertical relations

- relation attributes, meta information

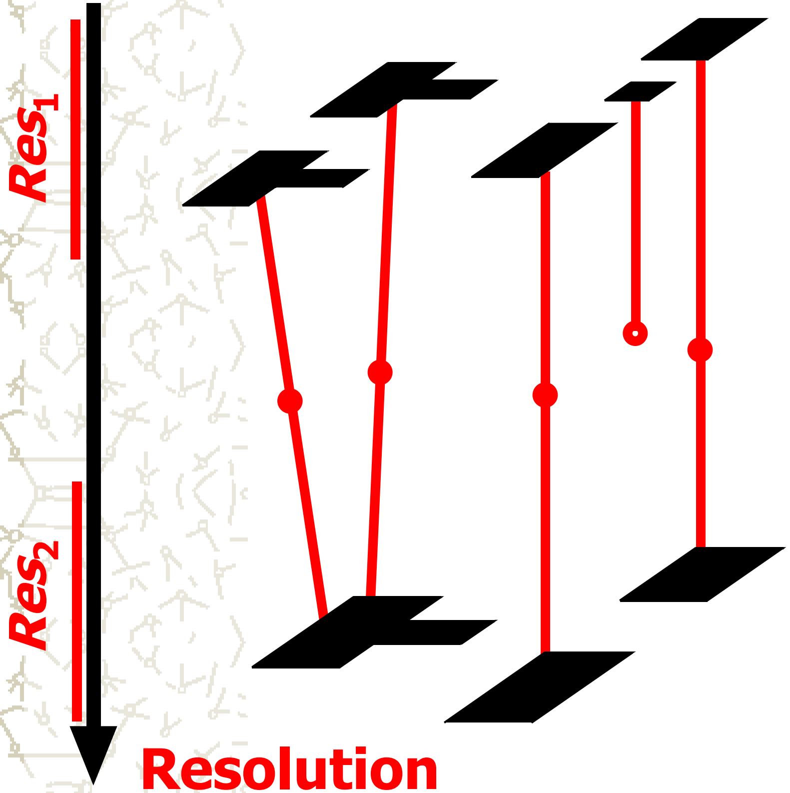



```
VERTICAL-RELATION / INTER-RESOLUTION-RELATION:

id: 0
origin: ID: 20; GenObjectClass: "geb-goldkueste3"
target: ID: 52; GenObjectClass: "geb-goldkueste3"
genSequence:
--id: 0
--consideredObjs:
--genOperation:
----id: 0
----genOperator:
------id: 30
------name:typification
------description:Typification Generalisation
------parameterDescription: [
--------Number of remaining objects; 10
--------Percentage of remaining objects; 60
--------Minimal distance between remain. Obj.; 10.0
--------consider number; false
--------consider percentage; true
--------consider minimal distance; false
--------]
----parameter: 10; 50; 10.0; false; true; false
--resolutionRelation: 0
```

Vertical relations

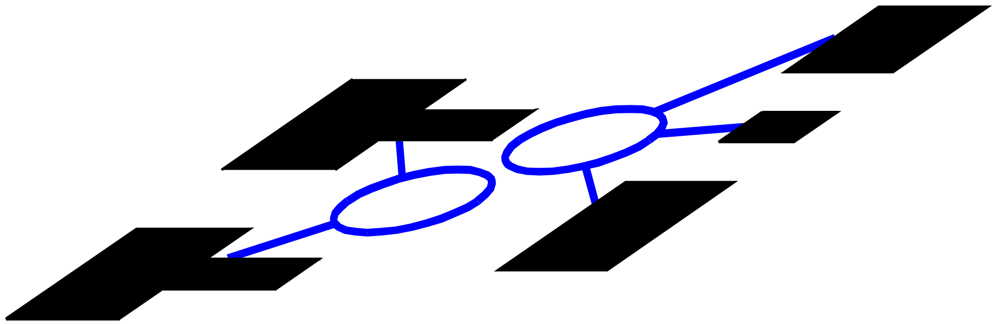
- example



Horizontal relations

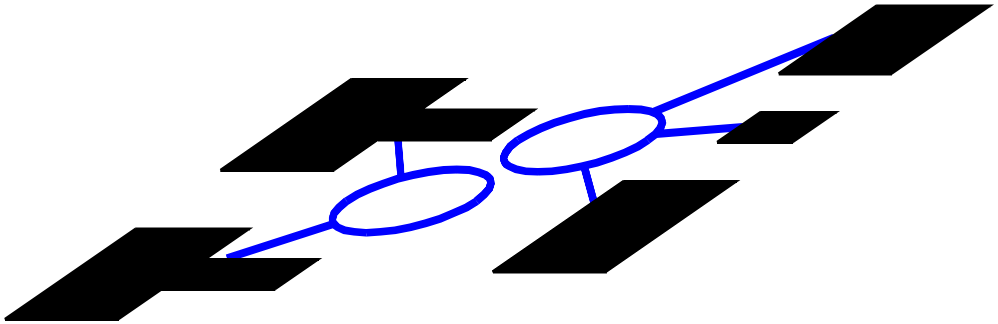
- Definition - Horizontal relations (HR) represent groupings of objects within the same resolution or level of detail
- this way an additional characterisation of objects through their neighbourhoods (geometric, semantic), also referred to as context modelling
- the degree of horizontal relations can vary between 1 ... n, depending on the number of participating objects
- a special case is the degree 1, e.g. if only one object is contained within a partition
- the number of horizontal relations is not limited – the decision for an explicit modelling depends on
  - application and use of HR
  - effort to produce the HR on-the-fly

context modelling

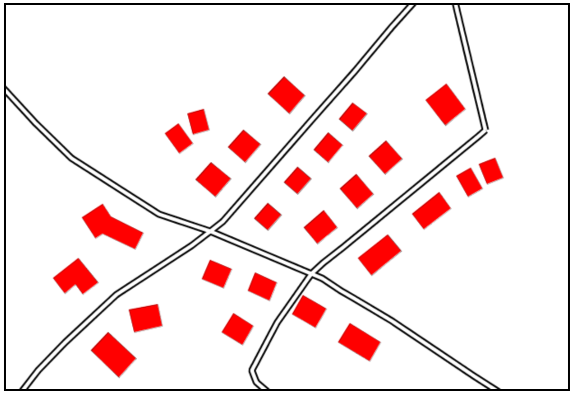


Horizontal relations

context modelling

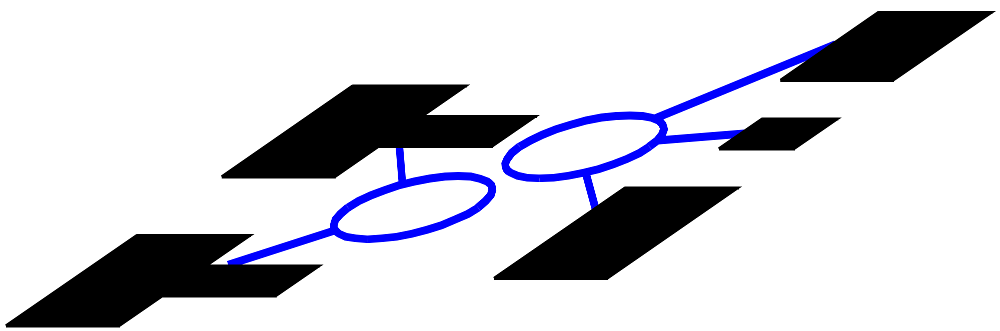


examples



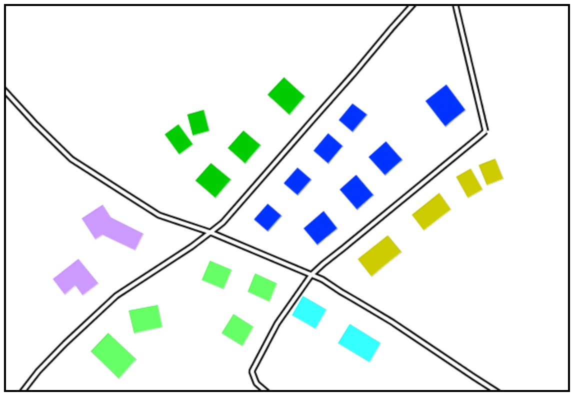
Horizontal relations

context modelling

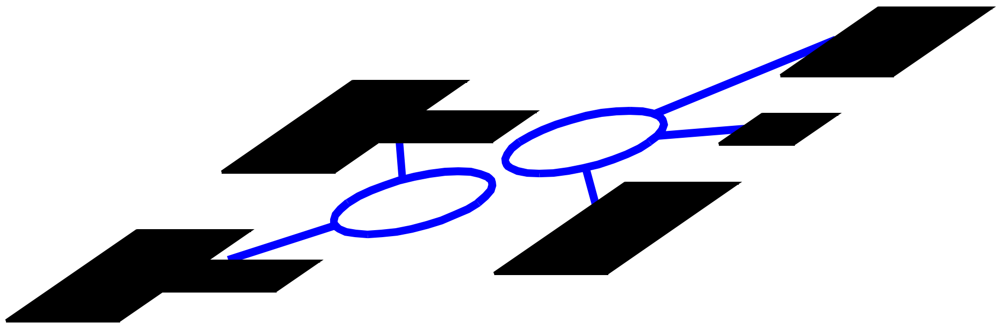


examples

- partonomic relations

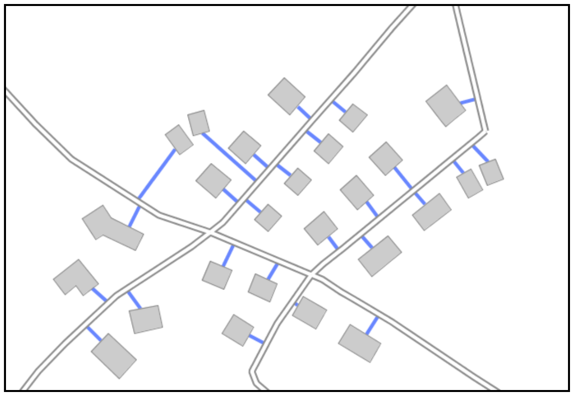


context modelling

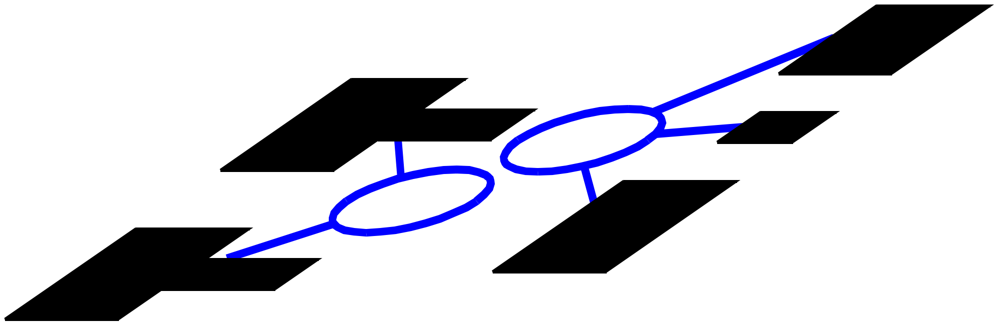


examples

- partonomic relations
- neighbourhood relations

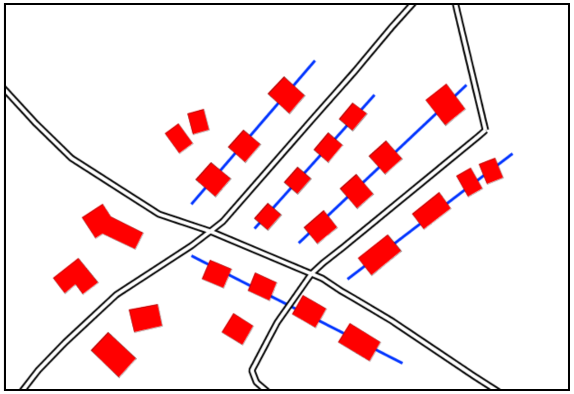


context modelling

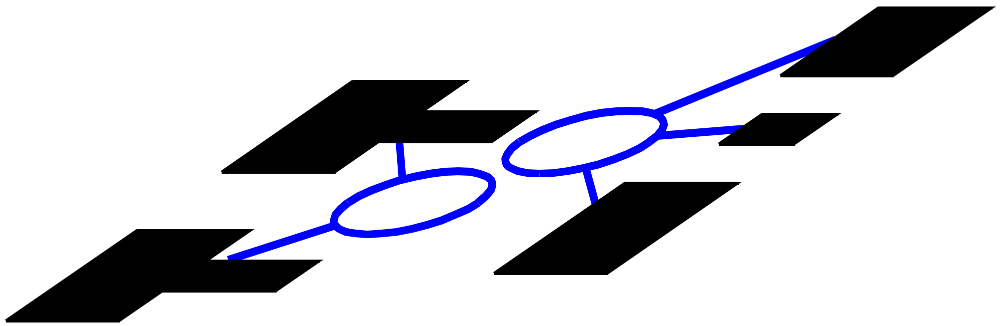


examples

- partonomic relations
- neighbourhood relations
- structural relations

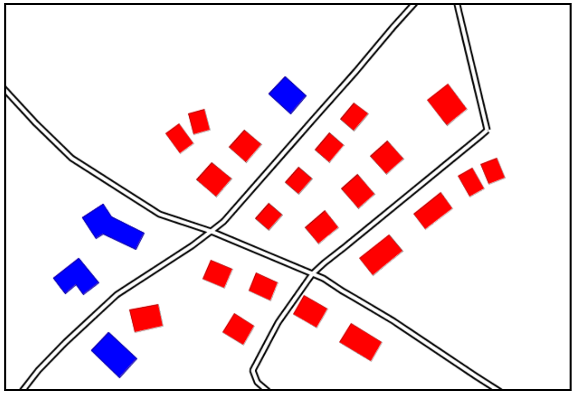


context modelling



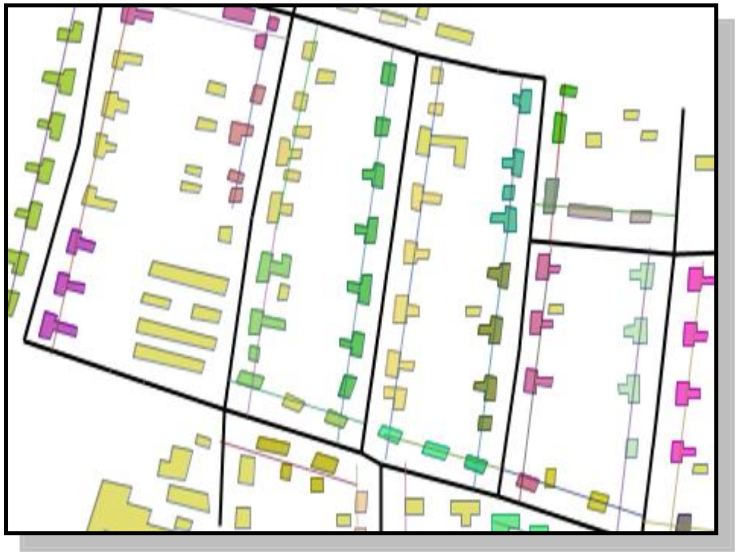
examples

- partonomic relations
- neighbourhood relations
- structural relations
- semantic relations



Derivation of horizontal relations – example of detecting building alignments

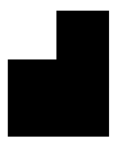
- focus on buildings situated near linear objects
- pre-selection with buffer operation
- evaluation of homogeneity based on similarity measures (size, shape, orientation, neighbourhood)



Horizontal relations

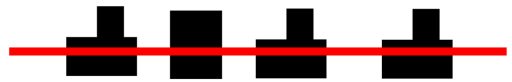
Homogeneity of building alignments

1. Calculation of individual measures for each building

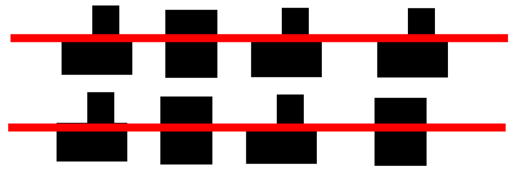


2. Calculation of variations within one group, e.g. maximum deviation from the mean

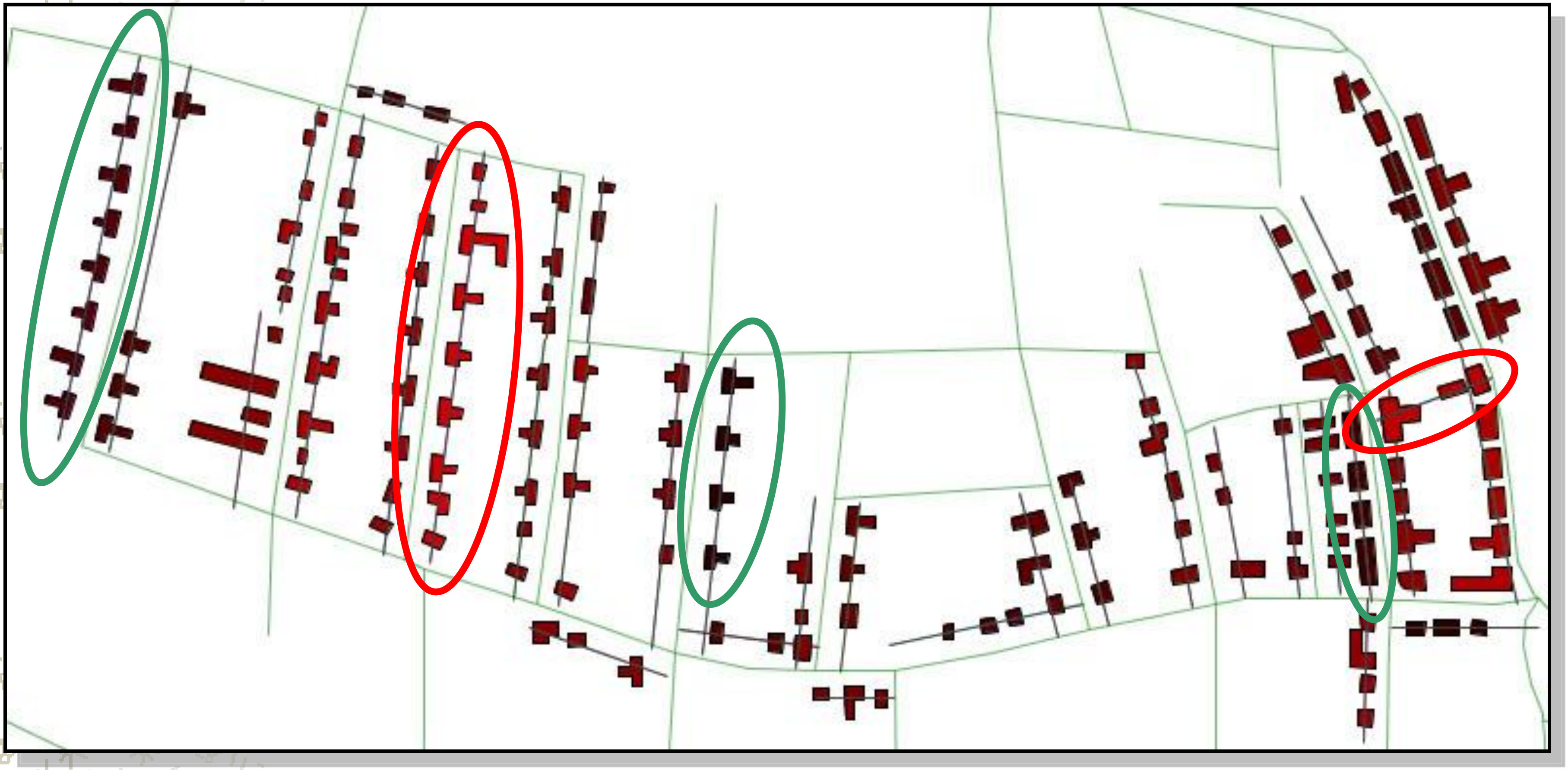
   $\sigma_{max}(A) = \max(A_{max} - A_{mean}, A_{mean} - A_{min})$



3. Comparison of deviations between different groups

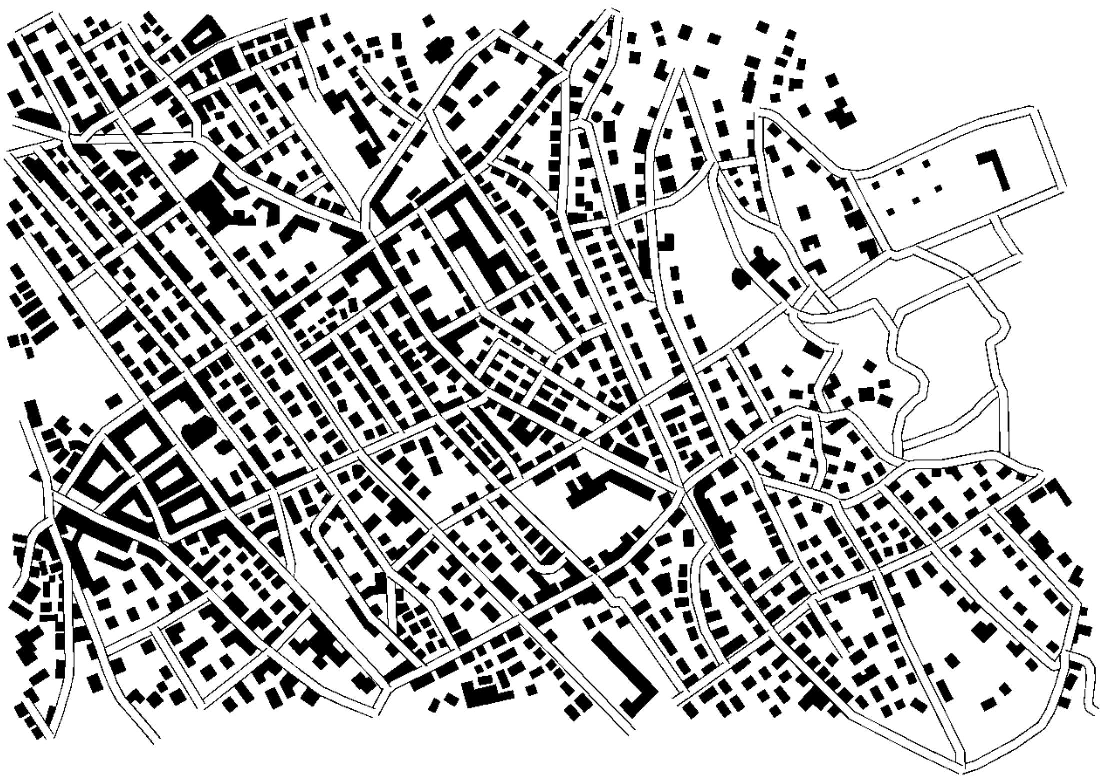


Horizontal relations



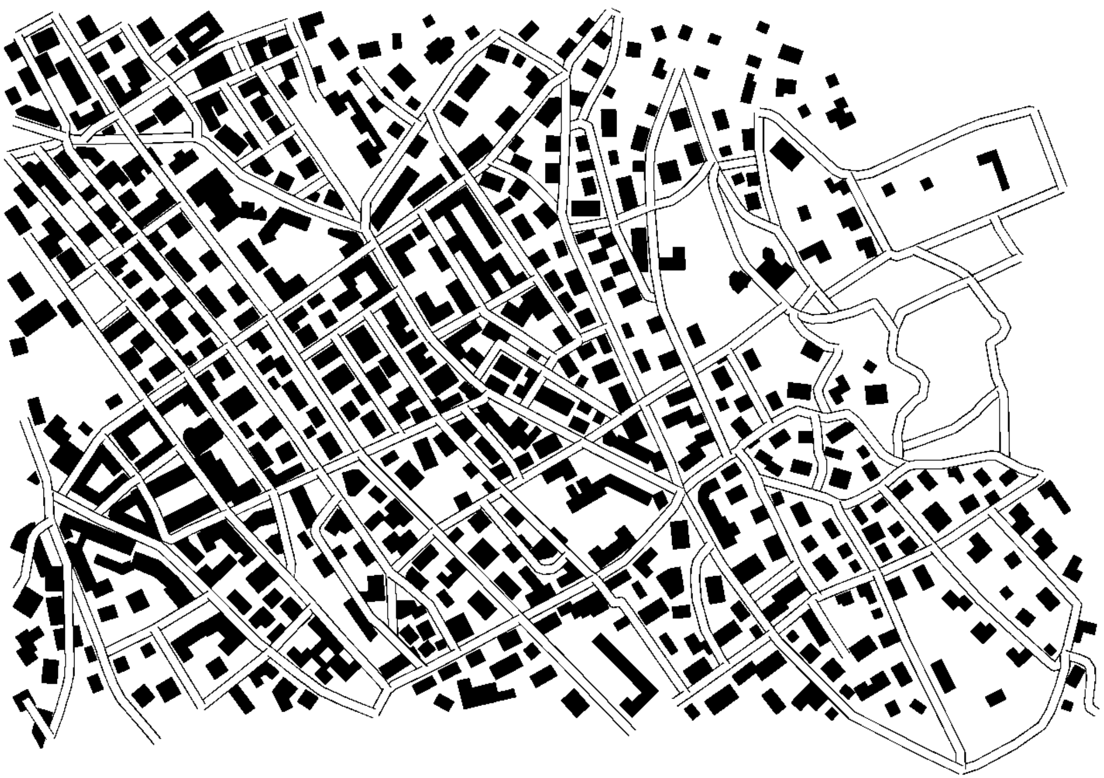
Homogeneity of building alignments

Horizontal relations



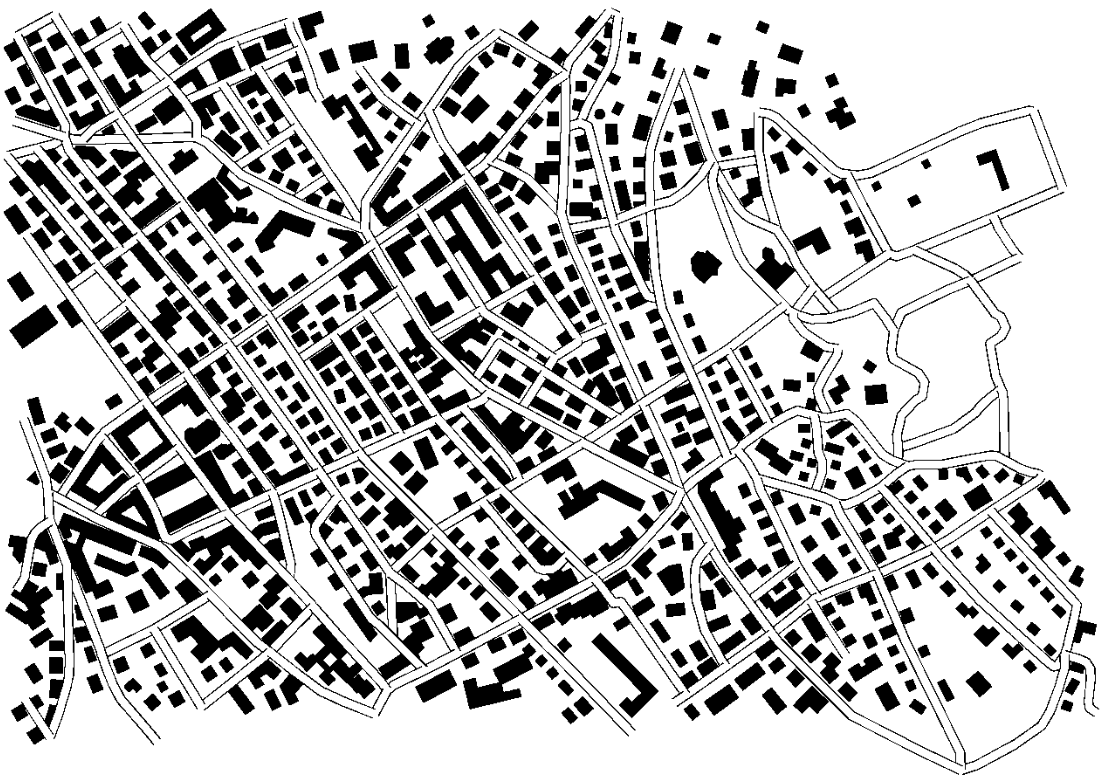
Original Vec25 without generalisation

Horizontal relations



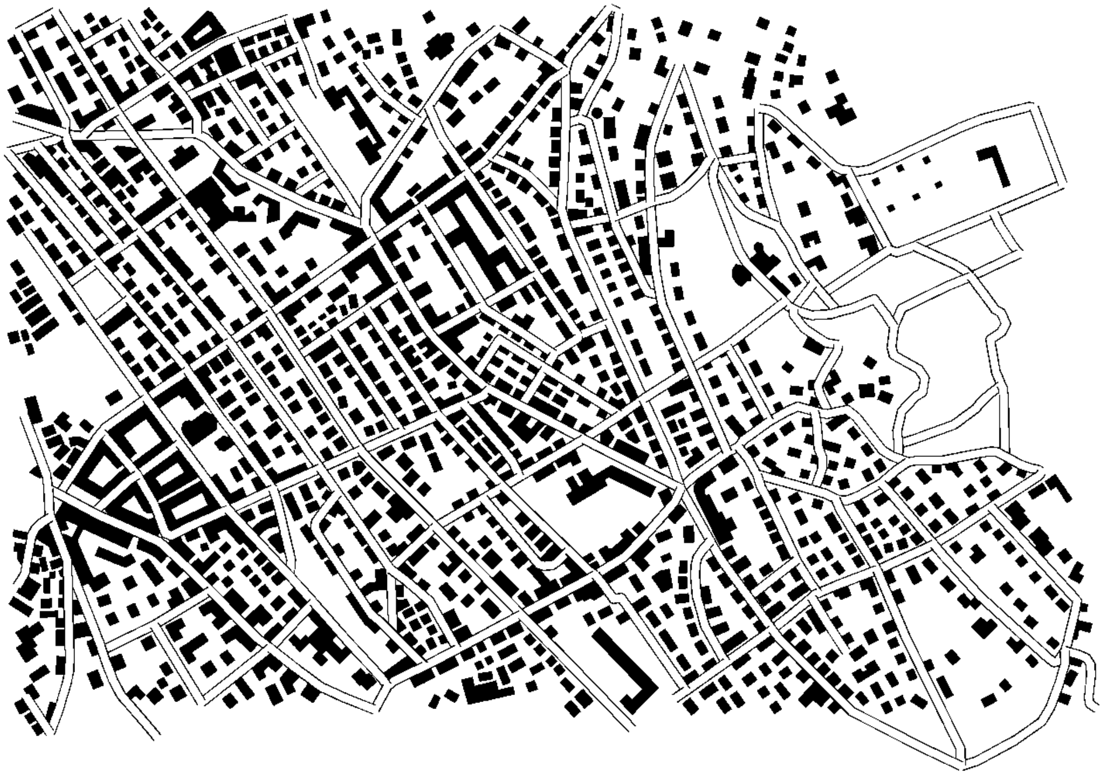
Automated typification for digital topographic map 1:50k (DTK50)

Horizontal relations



Automated typification for digital topographic map 1:50k (DTK50) with horizontal relations

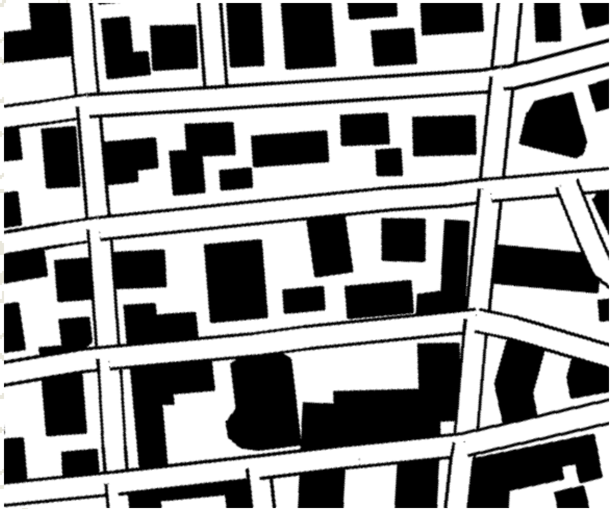
Horizontal relations

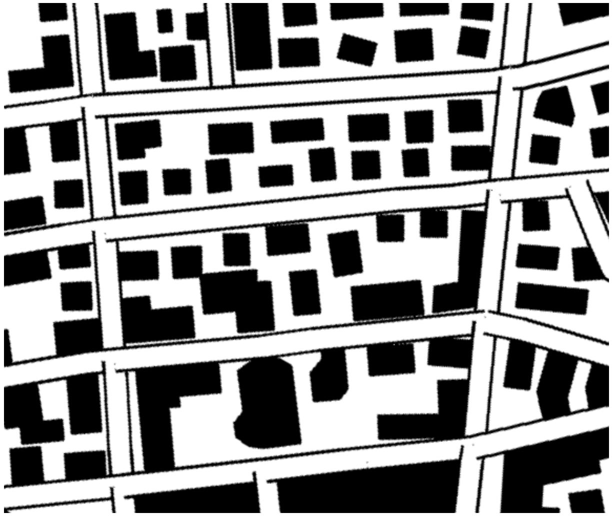


Original Vec25 without generalisation

Horizontal relations

Generalisation example





without   with

explicit modelled alignments base on horizontal relation

Where next

- we have to make tools for the creation of triangulations, auxiliary data structures and explicit relations more accessible
- further research on the usage of vertical relations required
  - e.g. for incremental updates
- utilisation of horizontal relations for the modelling of context
  - implementation through generalisation operators required
    → generalisation of object groups
  - utilisation within the agent framework through meso agents
- interplay between multi representation databases with fixed scales and vario scale data structures
  - usage of vario scale data structures for continuous zooming

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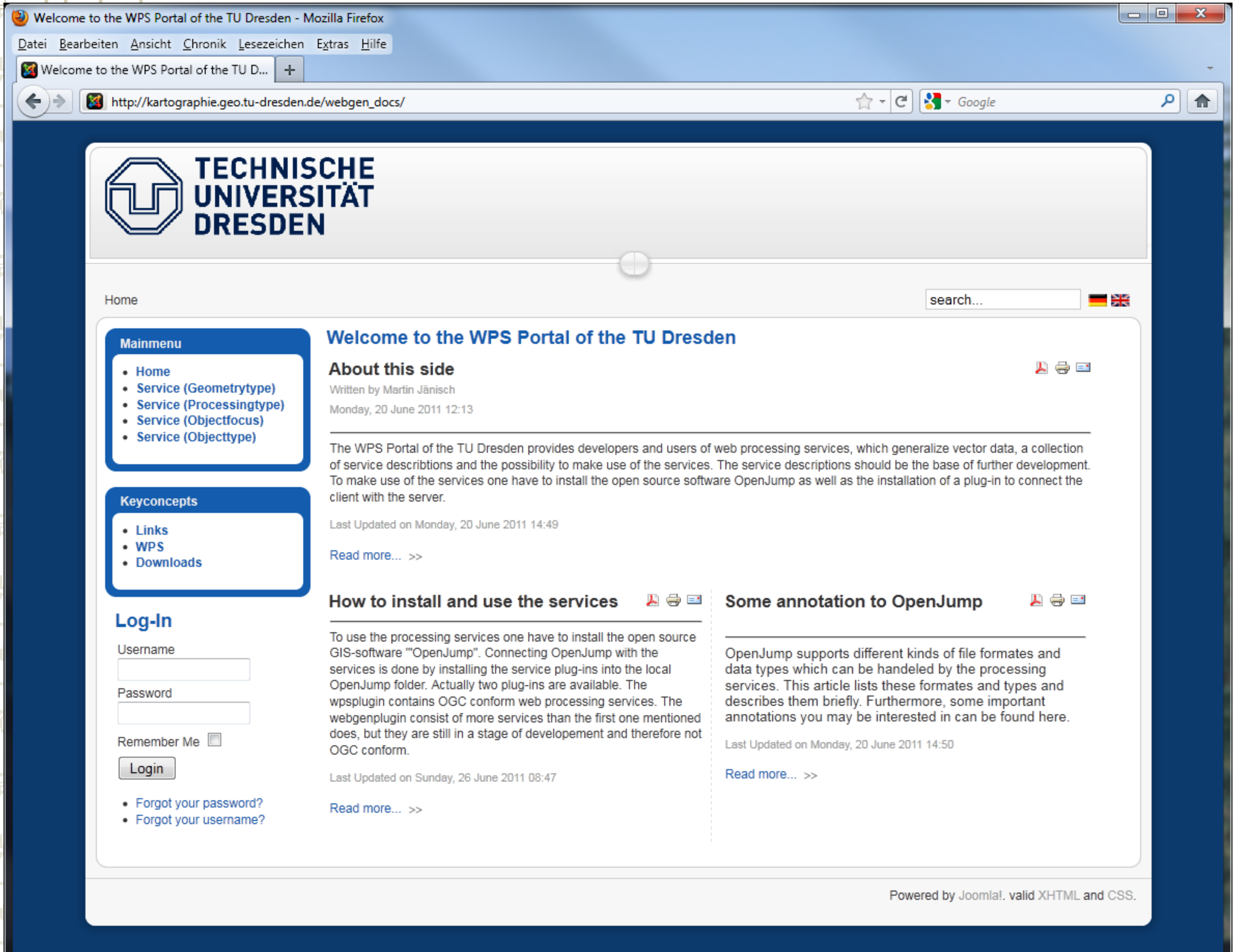
Summary



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Service (Processingtype)
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Welcome to the WPS Portal of the TU Dresden
About this side
Written by Martin Jänisch
Monday, 20 June 2011 12:13
The WPS Portal of the TU Dresden provides developers and users of web processing services, which generalize vector data, a collection of service describtions and the possibility to make use of the services. The service descriptions should be the base of further development. To make use of the services one have to install the open source software OpenJump as well as the installation of a plug-in to connect the client with the server.
Last Updated on Monday, 20 June 2011 14:49
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How to install and use the services
To use the processing services one have to install the open source GIS-software "OpenJump". Connecting OpenJump with the services is done by installing the service plug-ins into the local OpenJump folder. Actually two plug-ins are available. The wpsplugin contains OGC conform web processing services. The webgenplugin consist of more services than the first one mentioned does, but they are still in a stage of developement and therefore not OGC conform.
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Some annotation to OpenJump
OpenJump supports different kinds of file formates and data types which can be handeled by the processing services. This article lists these formates and types and describes them briefly. Furthermore, some important annotations you may be interested in can be found here.
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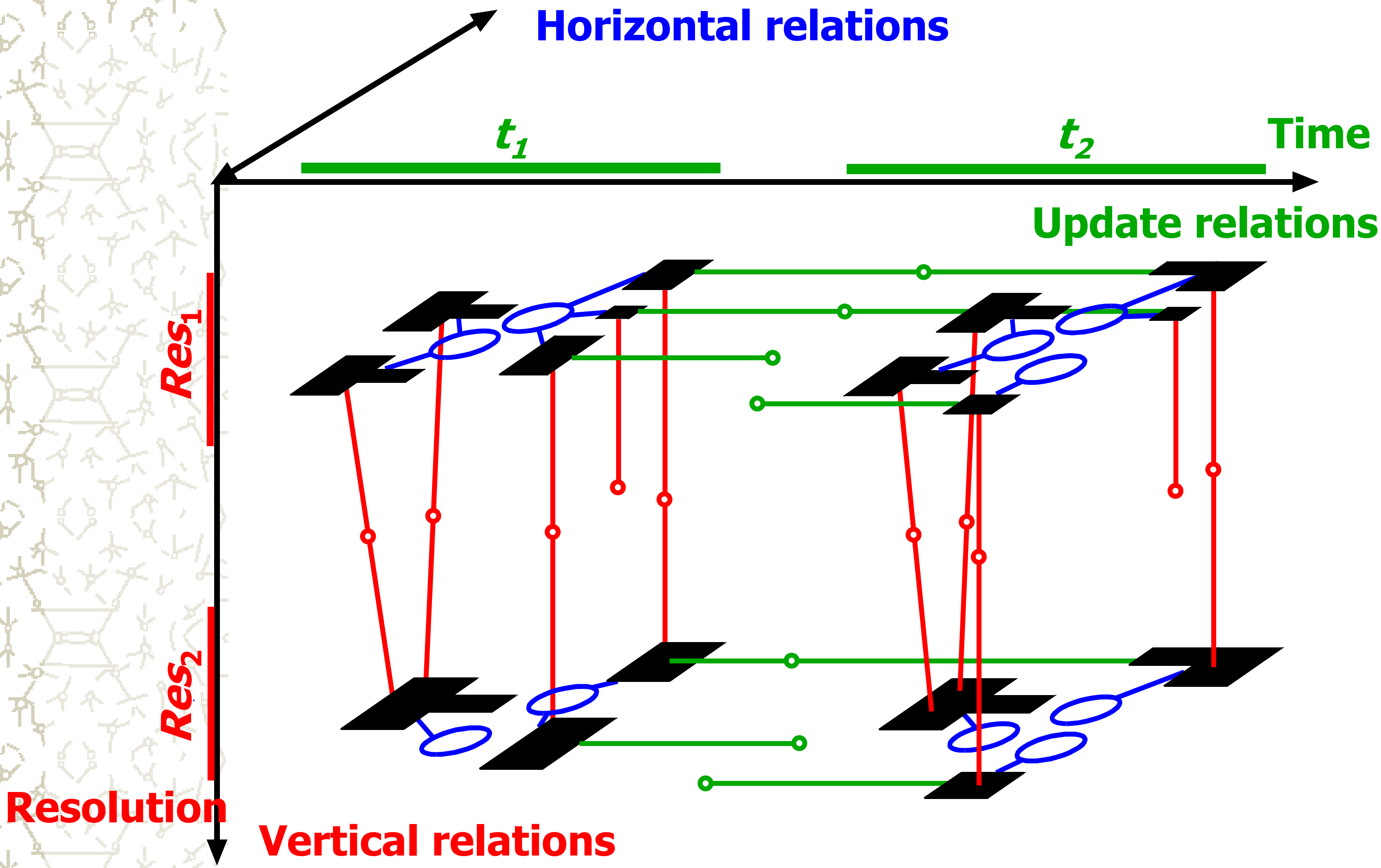
Data integration

several degrees of data integration can be distinguished

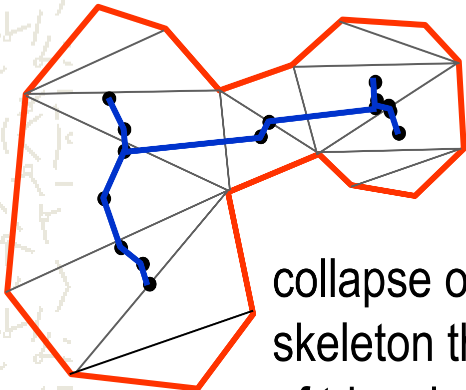
- integration of meta data:
  - standardised catalogue will help with selection of appropriate data set
- integration of semantic:
  - an integrated schema will be defined, which unifies the semantic of the different representations
  - additional rules has to be derived to enable an automated transfer according to the integrated schema
- complete integration:
  - through semantic integration only the schemata are combined within a common data model, objects which represent the same real world phenomena are not connected
  - with complete integration these objects will be identified and connected through explicit relations (links) within the database

Source: DEVOGELE, T., TREVISAN, J., RAYNAL, L. (1996),
Building a multi-scale database with scale-transition relationships.
In: Advances in GIS Research II: Proceedings 7th International Symposium on Spatial Data Handling.

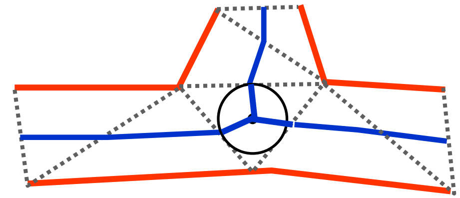
Relation modelling in MRDB



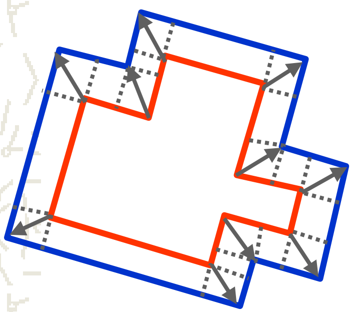
Applications of Voronoi, DT and CDT



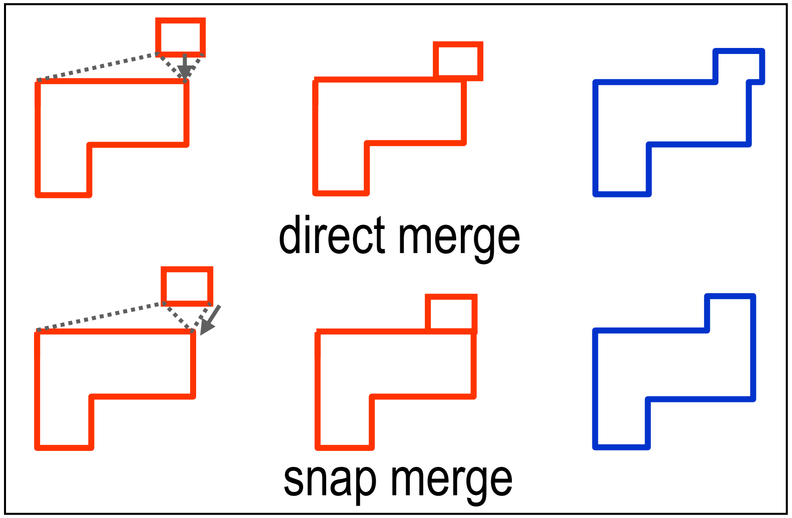
collapse of a polygon to a skeleton through centers of triangle circumcircles



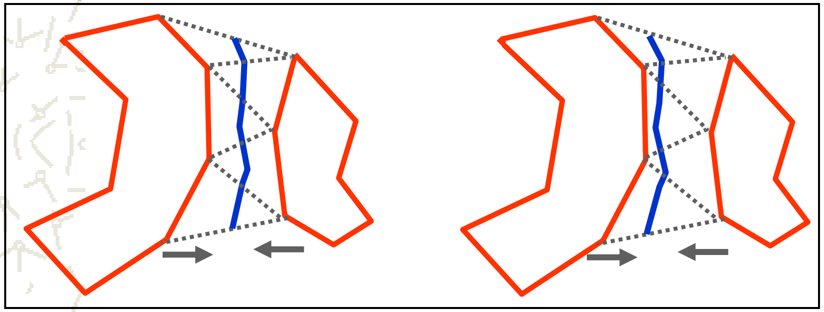
collapse of a ribbon-shaped object to a skeleton through the centers of triangle edges connecting opposite sides



graphic exaggeration of a concave polygon based on displacement vector of triangle nodes



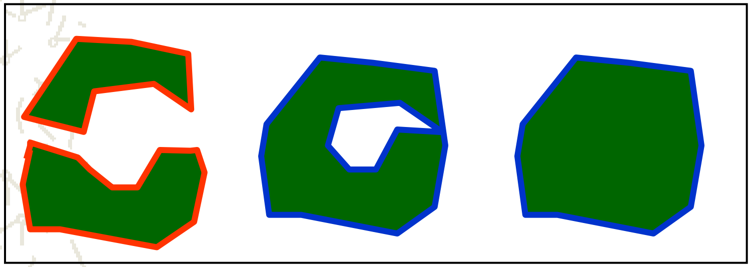
Applications of Voronoi, DT and CDT



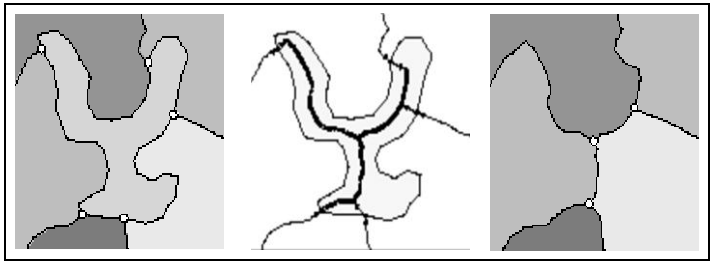
middle axis and weighted middle axis as merging boundary

(Jones et al., 1995)

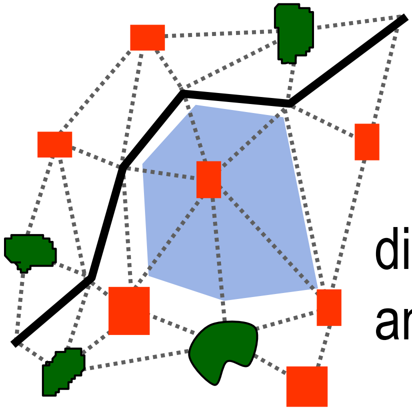
(Bader & Weibel, 1997)



adopt merge of natural objects

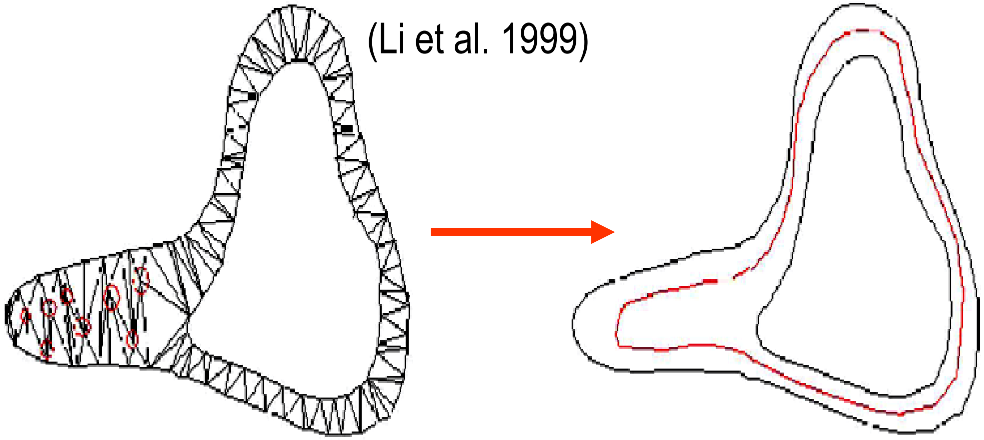


new allocation of eroded area

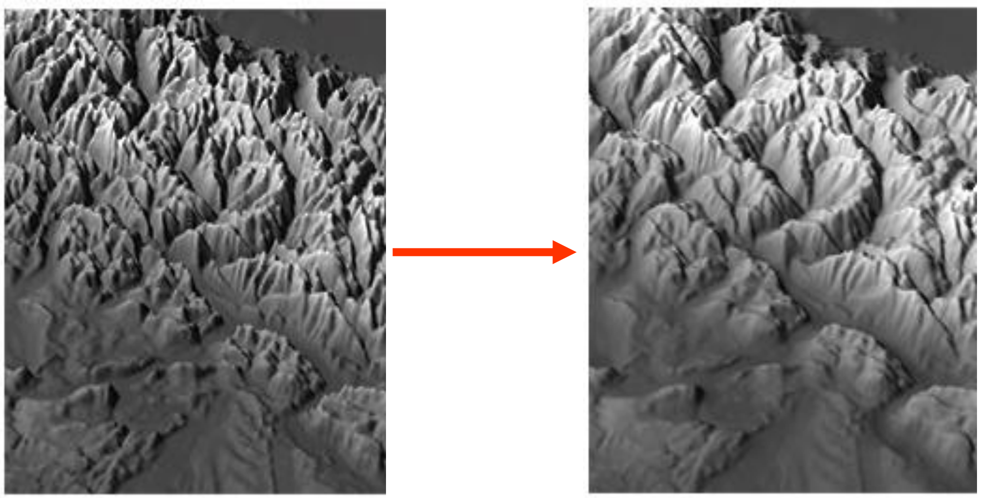


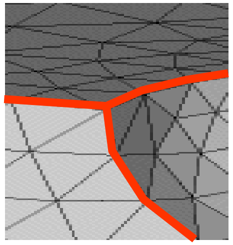
displacement buffer around an arbitrary object

Applications of Voronoi, DT and CDT



derivation of a new contour line based on CDT of existing contour lines and terrain points





generalization of terrain model by eliminating triangle edges below a sharpness threshold