ICA Tutorial on
Generalisation & Multiple Representation
2 July 2011 Paris

Lecture 2: Generalisation operators

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Agenda

- Operator vs. algorithms
- Classifications for generalisation operators
- Operators
- Examples of algorithms

Operators vs. algorithms

- Operator

  Particular type of transformation used during generalisation

- Algorithm

  Implementation of a particular operator, usually adapted for a particular context

Model / cartographic generalisation

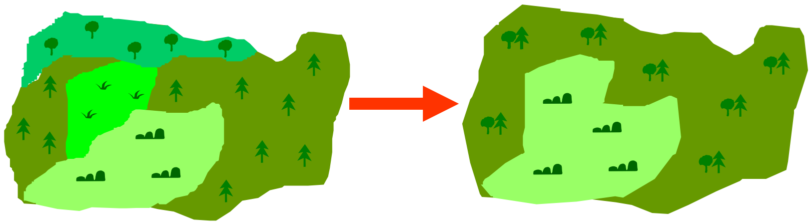
Defined in Brassel & Weibel 88

- Model generalisation

  Create a dataset with

  – Thematic requirements

  – Resolution requirements

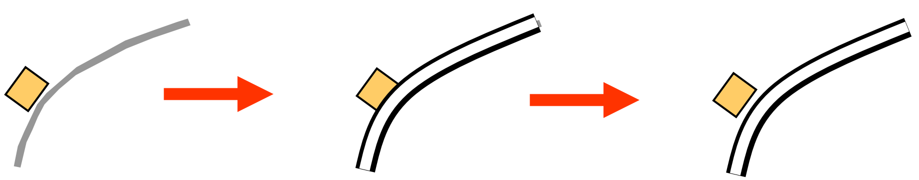


- Cartographic generalisation

  Create the map feature that conforms to:

  – Map specifications (map symbols defined by the legend)

  – Cartographic rules of legibility



Operator classifications

	McMaster & Shea
spatial transformations	Simplification Amalgamation Refinement Displacement Smoothing Merging Exaggeration Aggregation Collapse Enhancement
attribute transformations	Symbolization Classification

	Cecconi et al. (Agent)
<unspecified>	Thematic selection Thematic aggregation
individual objects	Weeding Unrestricted simplification Enlargement Exaggeration Fractalization Smoothing Rectification
individual or groups of objects	Selection Elimination Displacement
groups of objects	Amalgamation Combine Typification

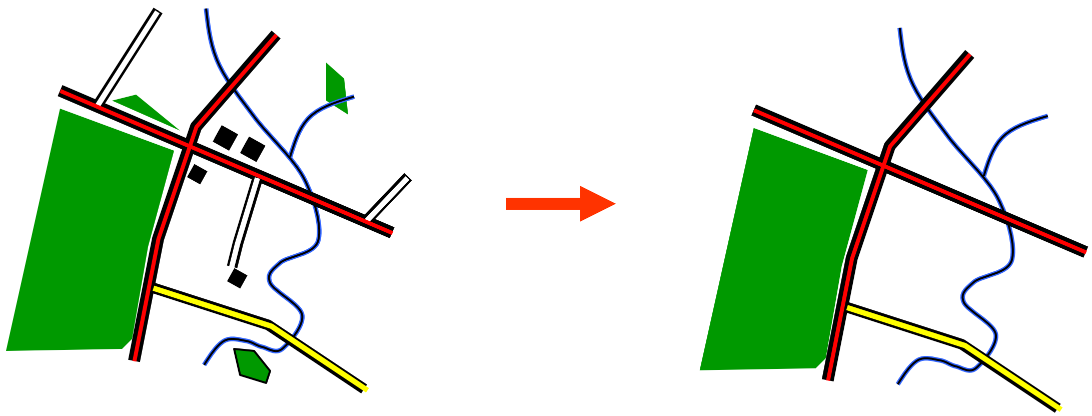
Yaolin et al.
Simplification Merge Amalgamation Aggregation Classification Selection

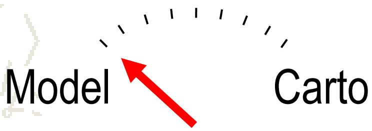
Model generalisation	**Cartographic generalisation**
Class Selection	Enhancement
Reclassification	Displacement
Collapse	Elimination
Combine	Typification
Simplification	
Amalgamation	

Foerster et al 2007

Class selection

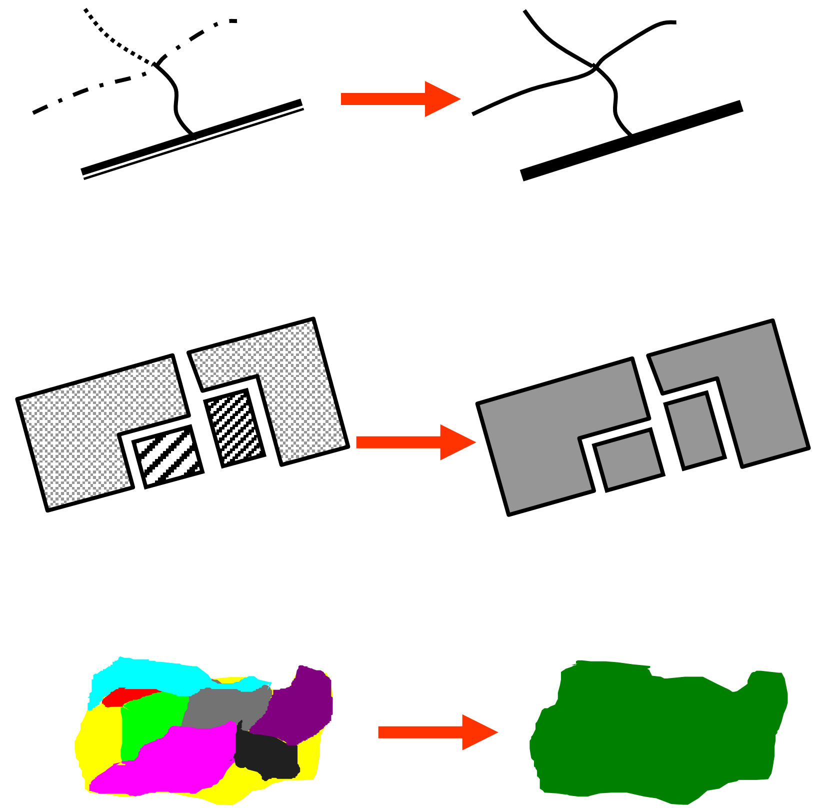
- Select the classes of features that the model contains
- Define the selection criteria for populating each class

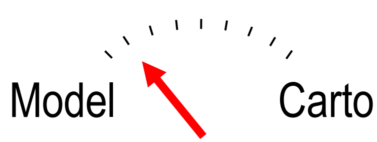




Reclassification

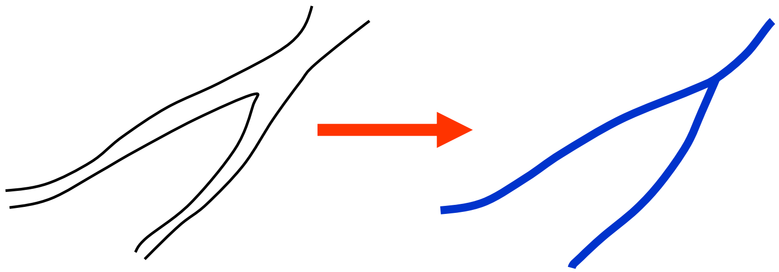
- It works on discrete objects or classes
- Common or dominant characteristics of the objects are preserved. Subtle distinctions are ignored.
- It results in reduced semantic variations and/or a higher level of semantic abstraction.

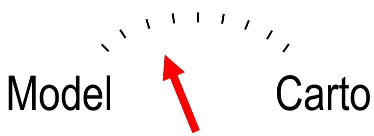




Collapse

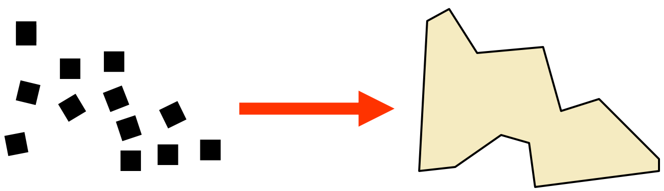
- Reduction in the geometric dimension
  - Area to line
  - Area to point
  - Line to point

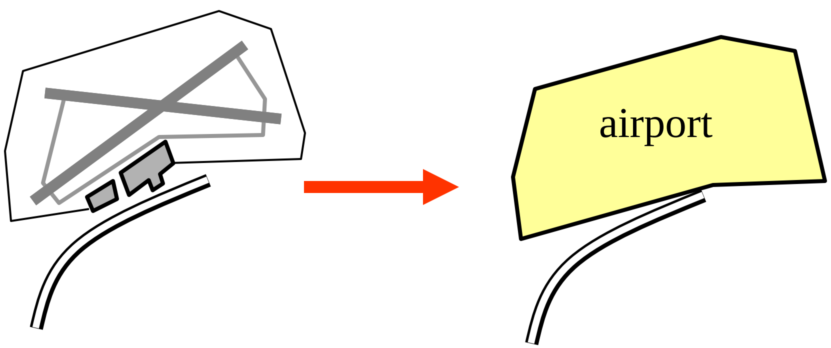


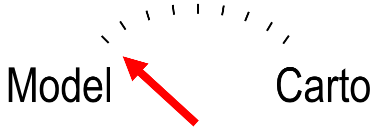


Combine

- Regrouping a set of feature into a more abstract feature, often of higher dimension

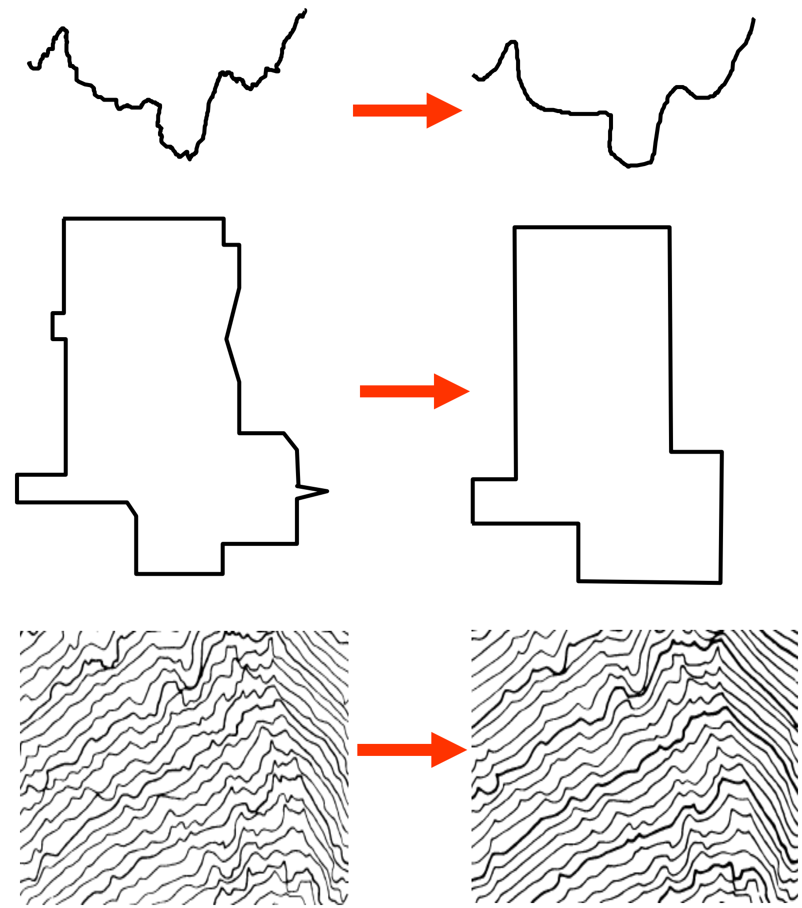


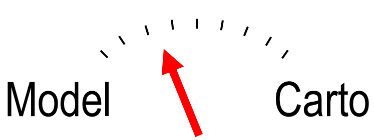




Simplification

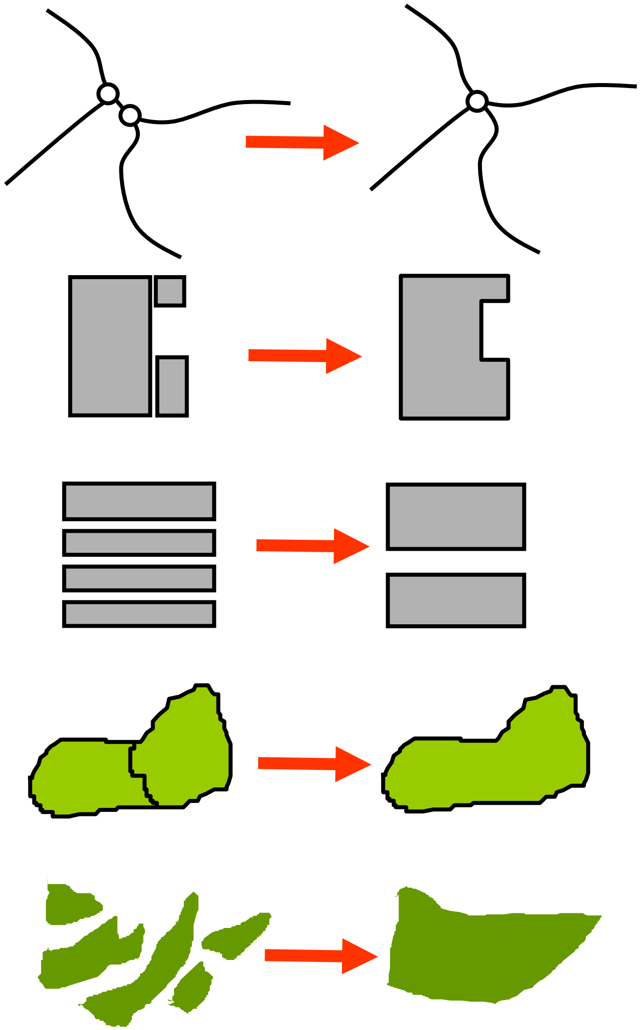
- It works on individual features
- Important details are preserved, unimportant details are eliminated.
- It results in a reduced graphic complexity of the affected object.
- It also results in geometries with less vertices

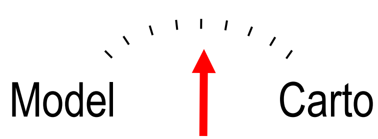




Amalgamation

- Many variations
  - It works on objects in close proximity.
  - Common boundaries, small gaps between neighbour objects are eliminated. General footprint are preserved.
  - It results in a reduced number of objects and an improved clarity.

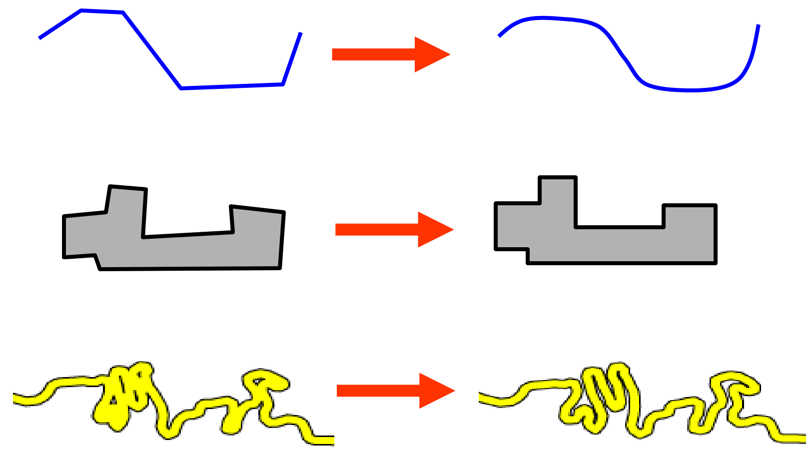


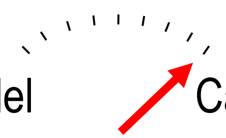


Enhancement

Make the shape of a feature more aesthetically pleasing

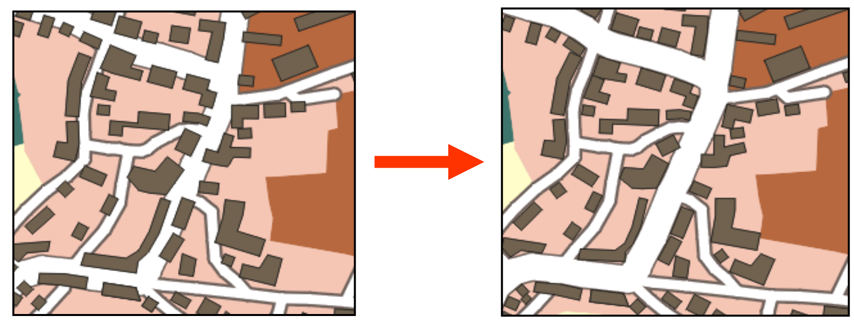
- Smoothing (for rivers, roads, lakes, contours…)
- Squaring (for buildings)
- Exaggerations

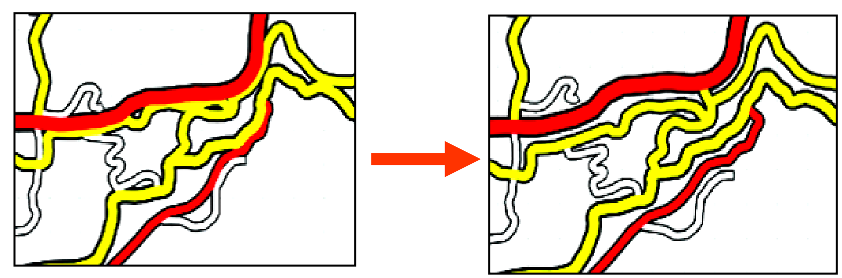


Model  Carto

Displacement

- It works on spatially congested objects.
- Important objects remain on their locations. Unimportant objects are moved away.
- It results in an improved clarity and correct map graphics.



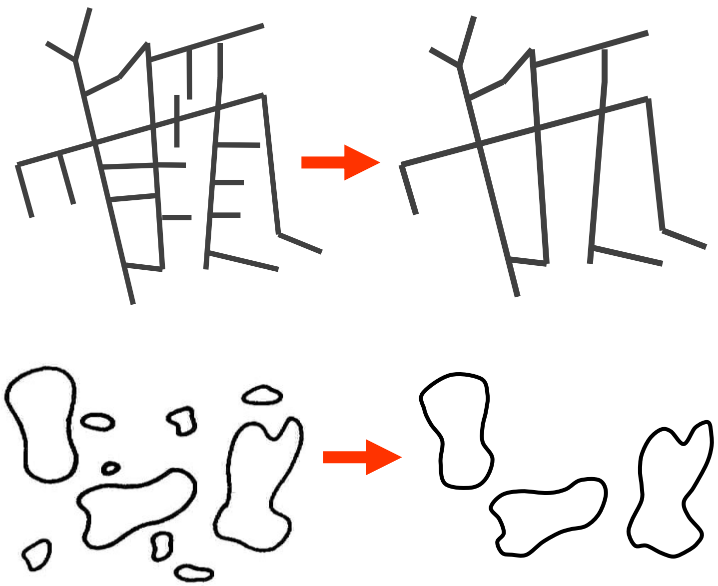


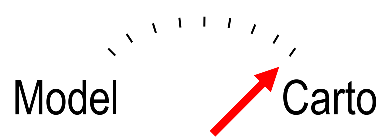
Model Carto

Elimination

- **Elimination**

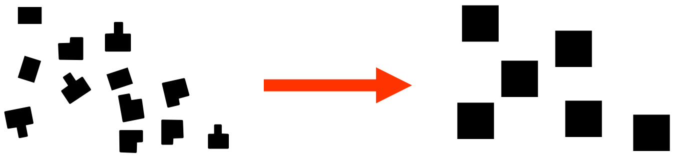
  when congestion occurs, unimportant objects are eliminated.

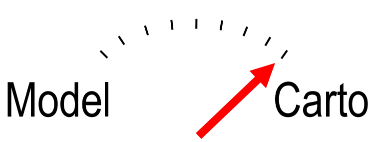




Typification

- **Typification**
- Reduces the number of objects
- Preserve their distribution / pattern





Algorithms

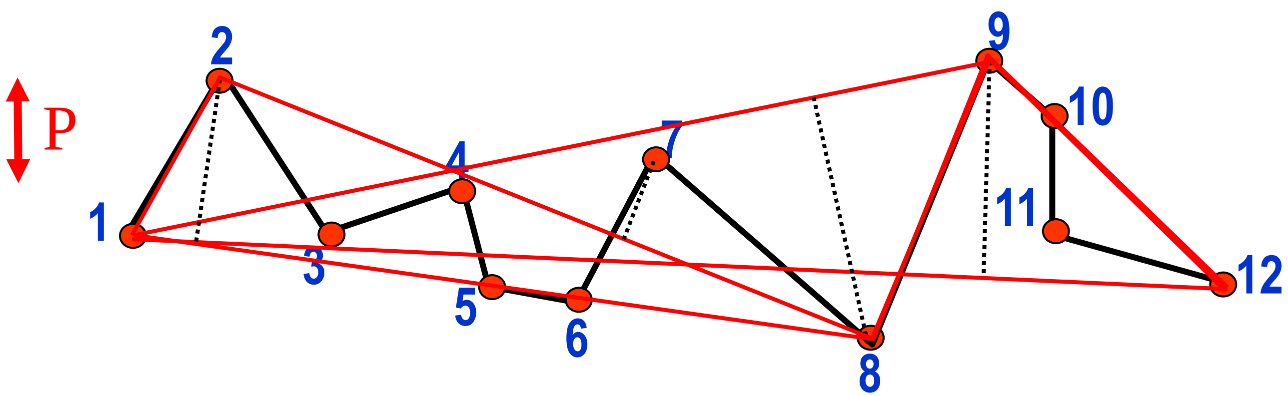
- **Independent algorithms:**
  - Implement 1 operator for 1 feature (simplification, smoothing, enhancement, collapse)
  - Many of them, well defined, available on GIS
- **Contextual algorithms:**
  - Implement 1 operator for a set of features (displacement, amalgamation, typification)
  - More complex, some starting to appear of GIS
- **Combined algorithms:**
  - Implement several operators
  - What to apply where, in which order
  - generalisation process => Next presentation by Lars Harrie

- **Algorithms for 2D vectors, 3D vectors, raster**

Independent algorithms: Douglas-Peucker

It selects characteristic points on a line, *P* = tolerance length

1. define a straight line segment between the terminating points
2. measure the perpendiculars between the line segment and the intermediate points
3. split the line into two parts at the furthest point beyond *P*
4. repeat 1-3 on the two resulting parts until all perpendiculars fall within the tolerance

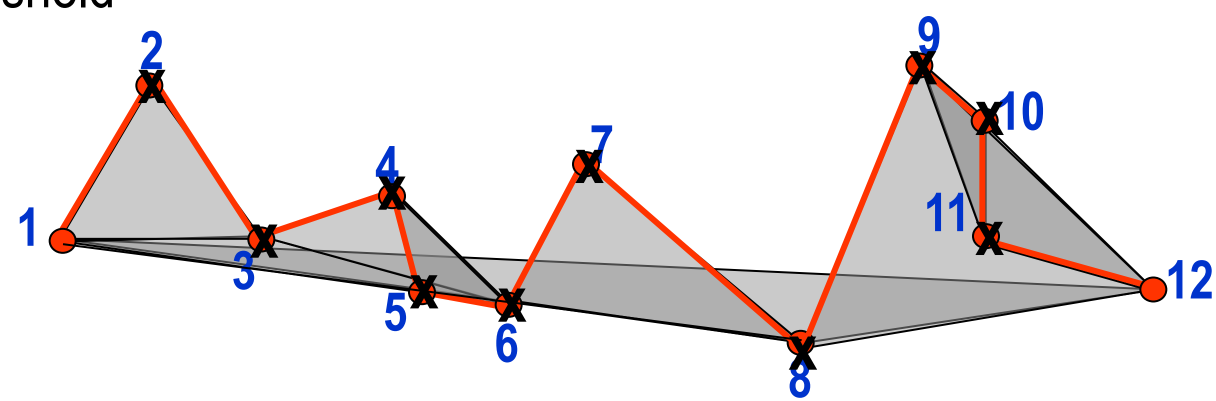


important 9, 8, 2, 3, 7, 6, 11, 4, 5, 10 unimportant

Independent algorithms: Visvalingham-Williamson

It eliminates unimportant points on a line, *P* = tolerance area

1. measure the relative importance of the intermediate points
2. eliminates the least important point, e.g. the point with the smallest area of the triangular feature (<*P*) formed by connecting the point with its two neighbors
3. repeat 1-2 until all remaining points are beyond the importance threshold

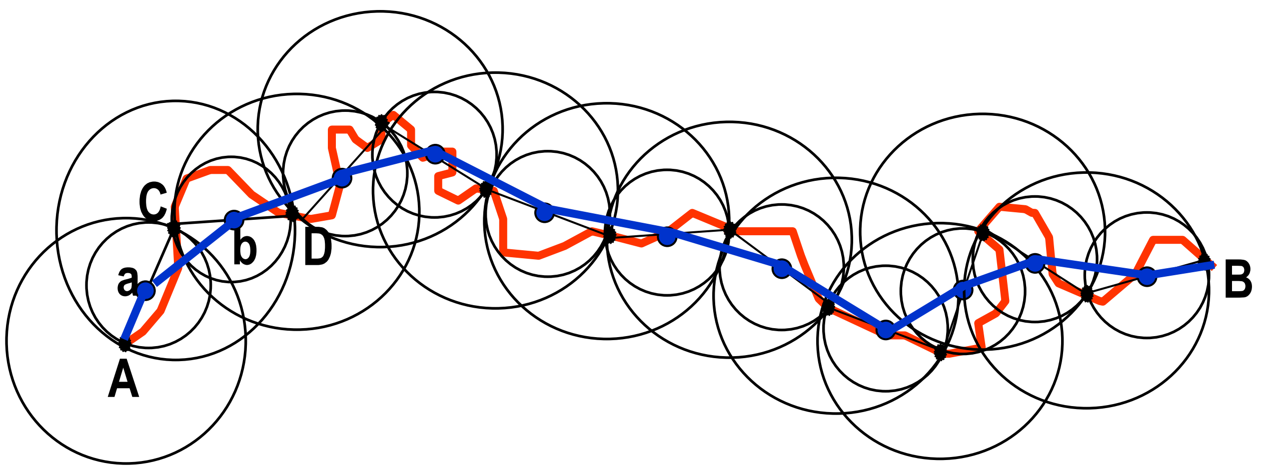


unimportant **10, 5, 4, 11, 2, 3, 7, 6, 9, 8** important

Independent Algorithms - *Li-Openshaw*

It smoothes a line, *P* = tolerance length

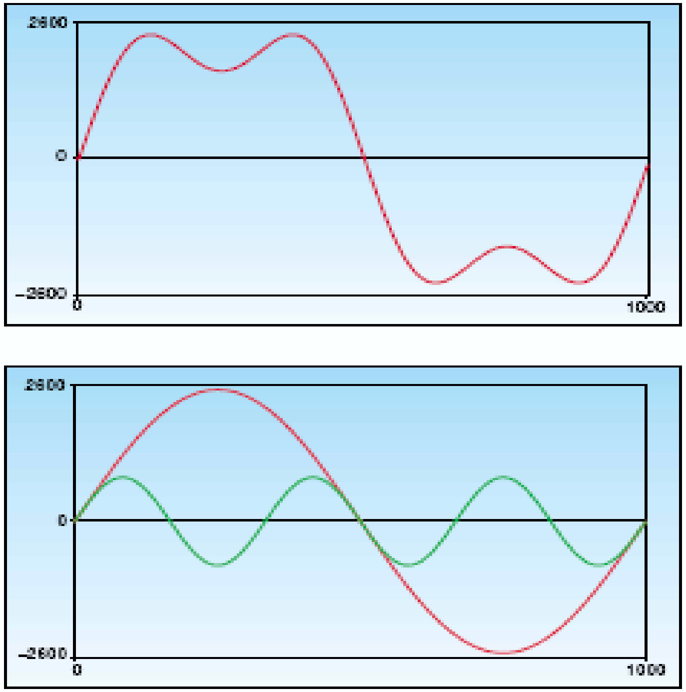
1. draw a circle at starting point A with diameter double so much as *P*, which intersects the point C on the line
2. draw a circle with AC as diameter. The center 'a' along the straight line section AC is selected as a point along the generalized line
3. set C as the new starting point and repeat 1-2



Algorithms – Fourier Transform

It smoothes a spectrum line globally, *P* = the number of Fourier coefficient pairs

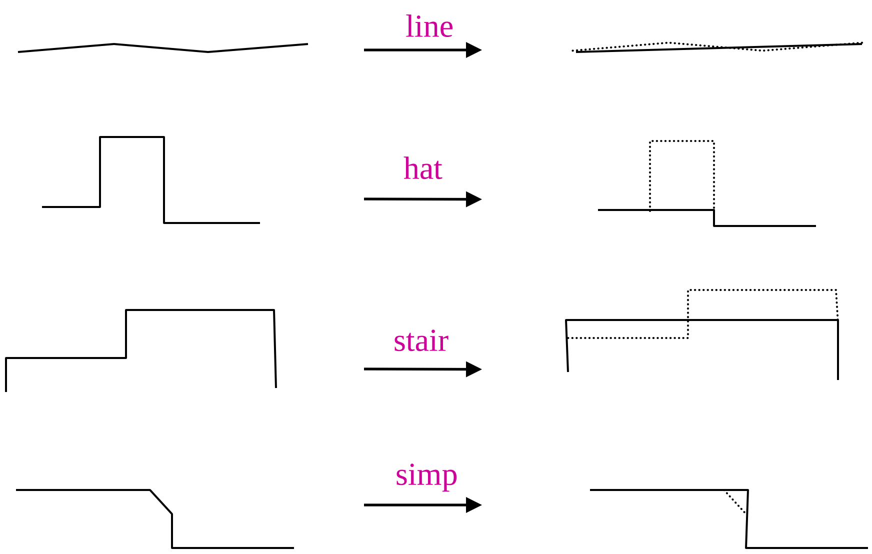
- Any spectrum can be approximated by the summation of a series of sine and cosine waves. The determination of sine and cosine components of a given spectrum is known as FT.
- FT converts the time domain to frequency domain. The useful information is found at lower frequencies and the higher frequencies can be ignored.



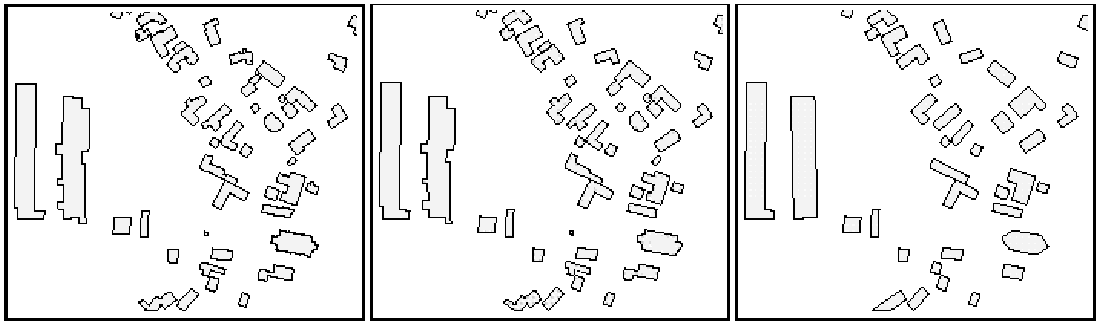
An original spectrum (top) and its sine components (bottom)

Independent algorithms: building simplification

- Remove shape details without loosing the characteristic shape (right angles)

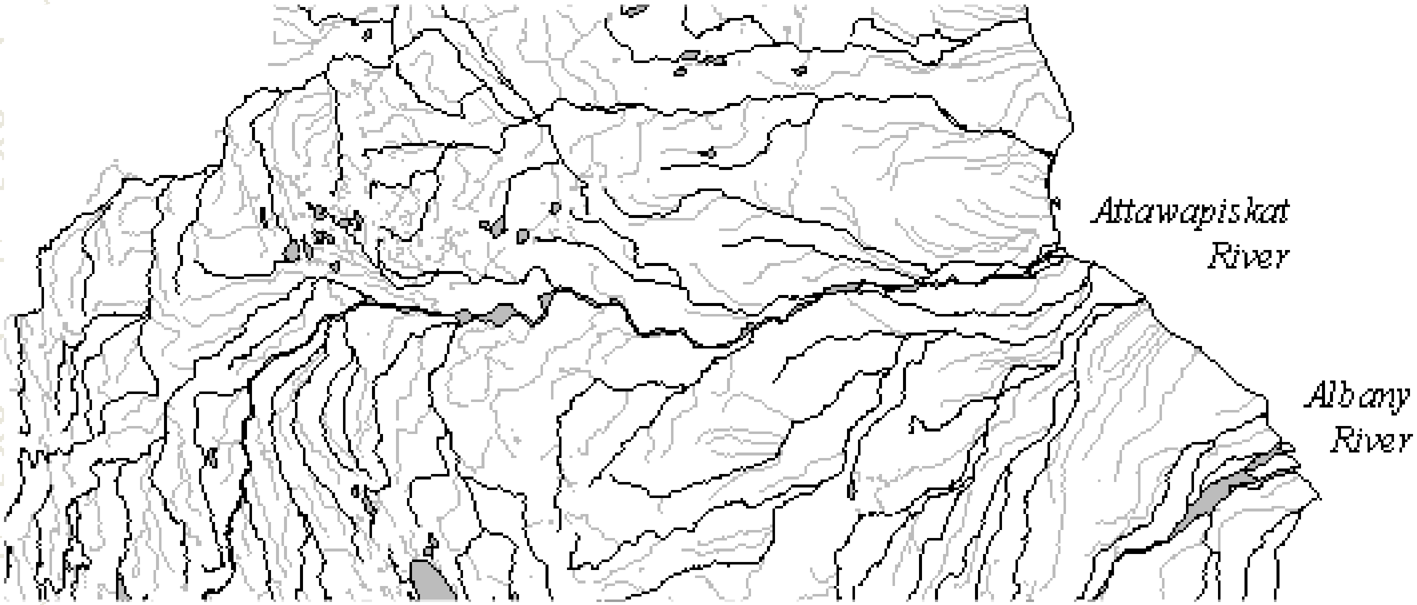


- Ex: Algorithm developed in Hannover (Sester 2005)



Contextual algorithms: network simplification

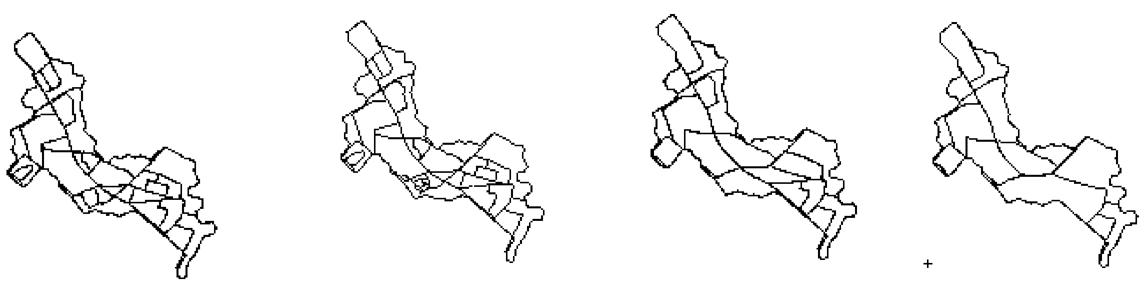
Simplification of a hydrology network using the good continuation principle (Thomson and Brooks 2000)



Contextual algorithms: network simplification

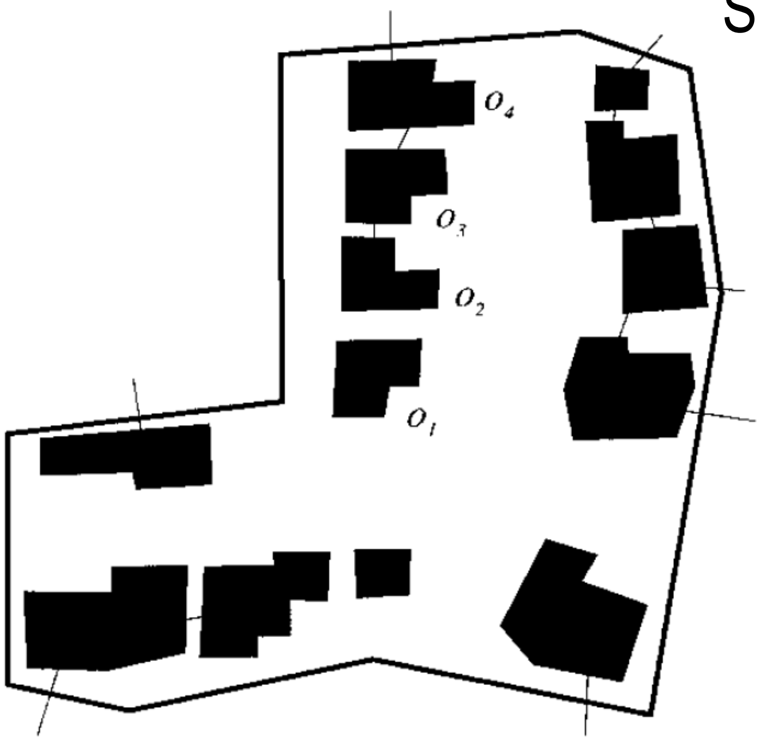
- Road network simplification, based on strokes

  (Edwardes and Mackaness 2000)



Contextual algorithms: displacement

Simulated annealing



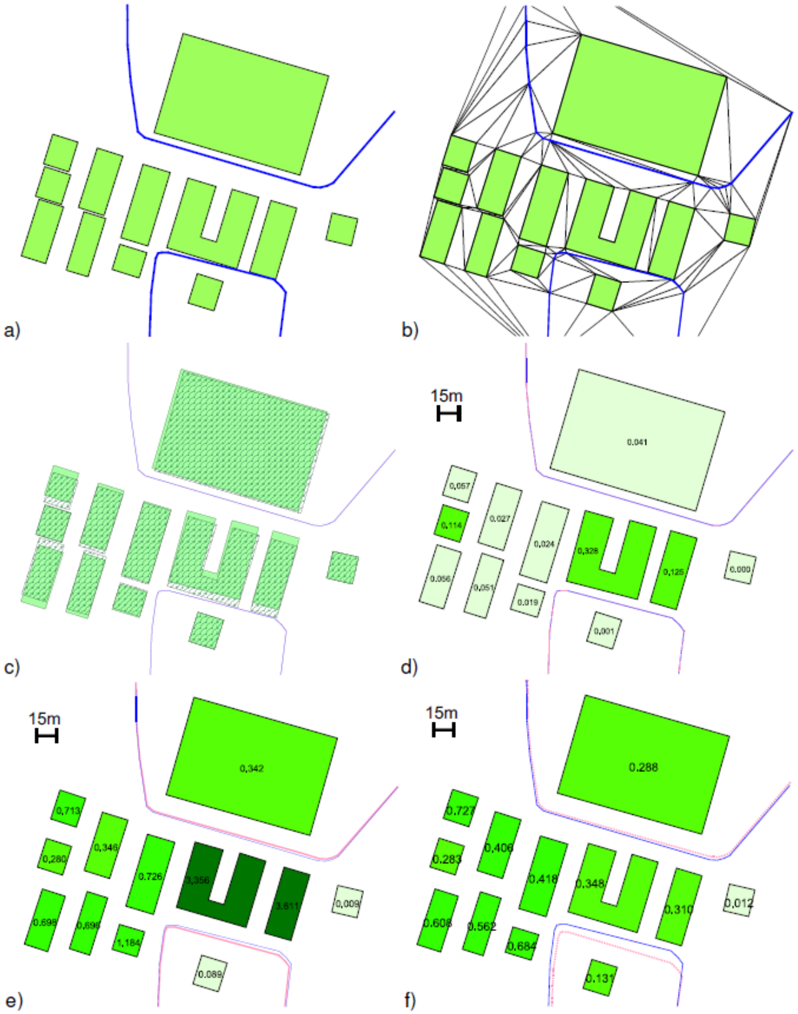
Original map
with conflicts (segments)

Conflicts resolved

(Ware & Jones, 1998)

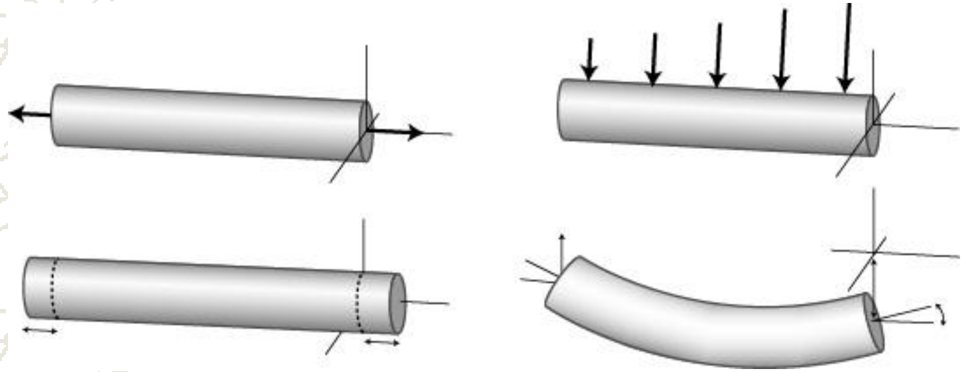
Contextual algorithms: displacement

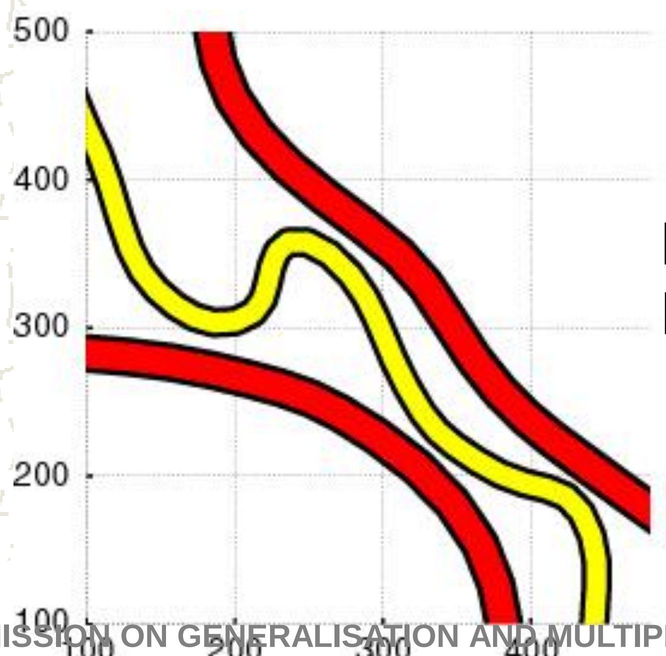
Displacement based on least square adjustments (Sester 2005)



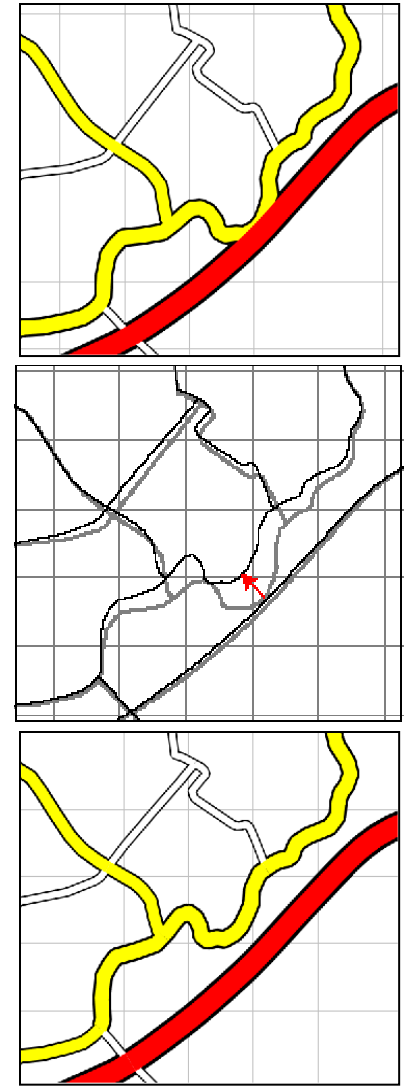
Contextual algorithms: displacement

Coaxial load   Transversal load



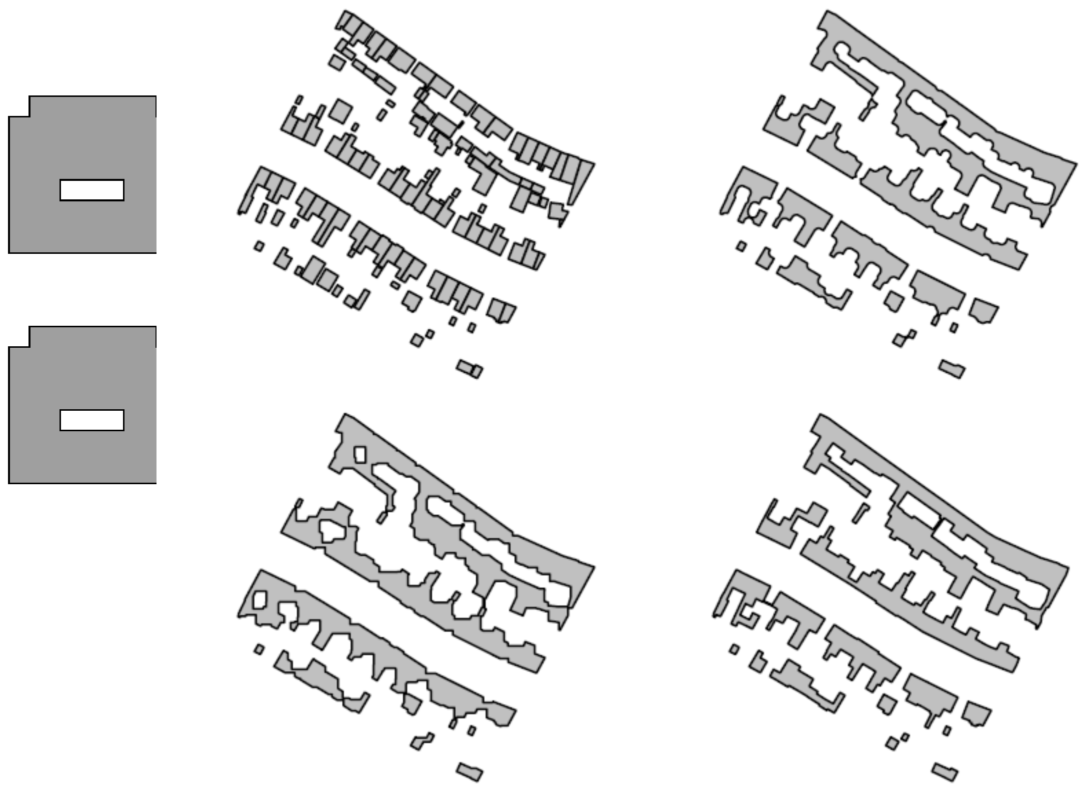


Elastic beams
From Bader (2001)



Contextual algorithms: amalgamation

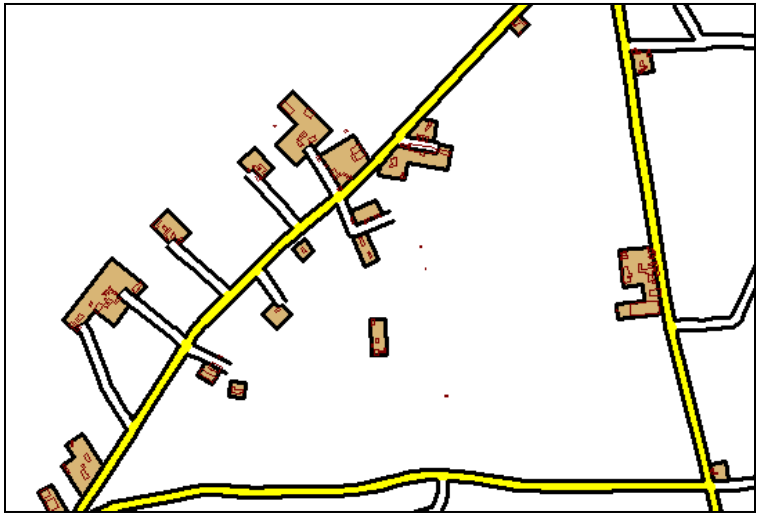
Amalgamation using Minkowski sums (Damen et al 2008)



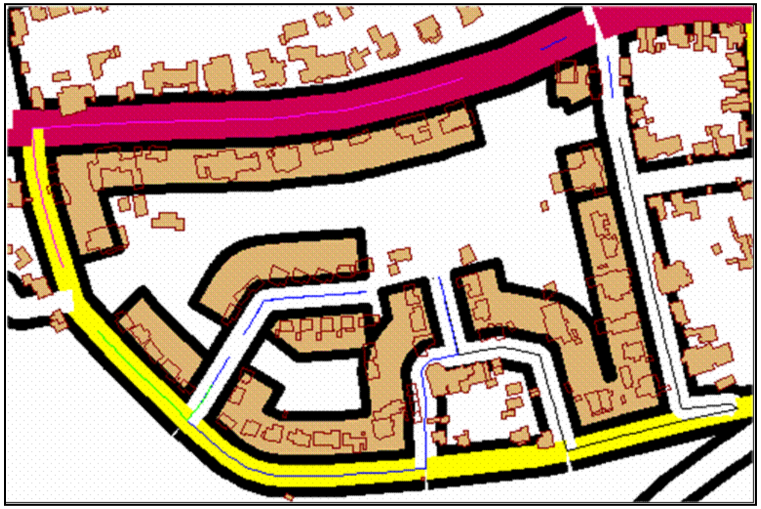
Contextual algorithms: amalgamation

Regnauld & Revell 2007

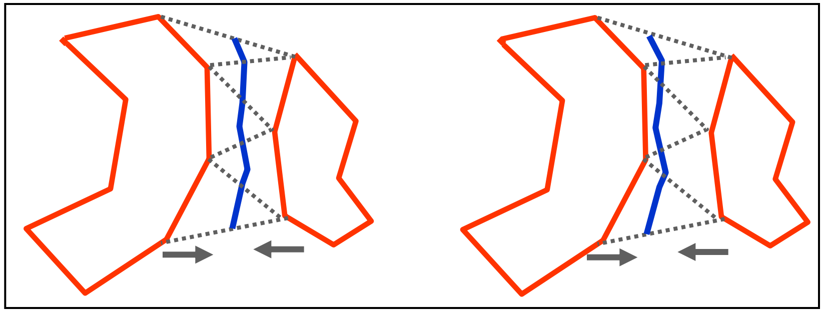
- Rural context



- Urban context



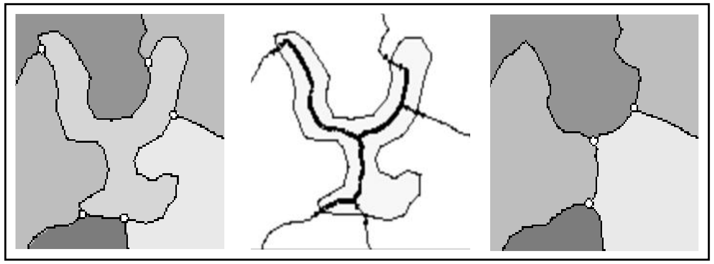
Contextual algorithms: amalgamation



middle axis and weighted middle axis as merging boundary

(Jones et al. 1995)

(Bader & Weibel, 1997)



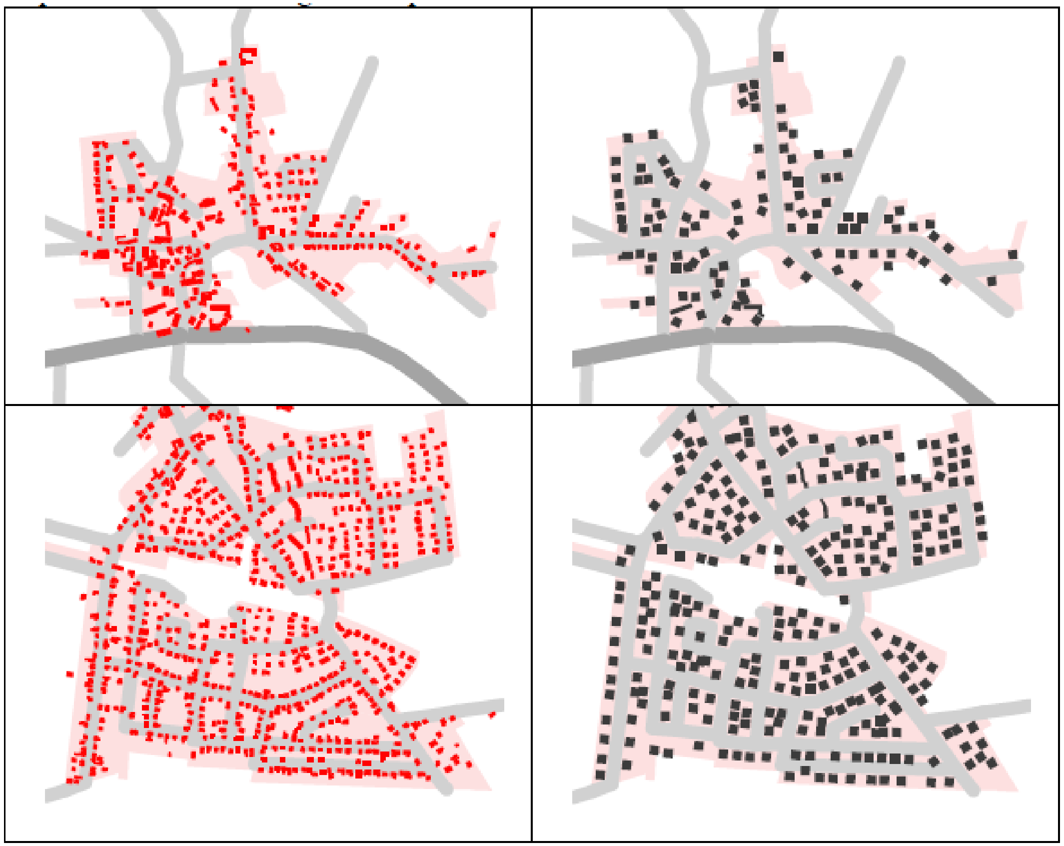
Collapse, split, reclassify and merge

Contextual algorithms: typification

Building typification based on Minimum Spanning Trees (Regnauld 2001)

Contextual algorithms: typification

Building typification based on Self Organised Maps (Sester 2005)



Algorithms - morphological transformations

- **Used a lot for processing raster data (including DTM)**
- **Morphological transformations**

  Different iterations and sequences of dilation and erosion lead to simplification, amalgamation, expansion & shrinkage, and elimination:

A

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	0	0	0	0	1	0	0
0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0
0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	0
0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0
0	0	1	0	0	0	1	1	1	1	1	1	0	0	0	0
0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0
0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

C* = dilation of *A* by *B

0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0
0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0
0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0
0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0
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0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0
0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0

D* = erosion of *C* by *B

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0
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0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

$$B = \begin{matrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{matrix}$$

First dilation, then erosion results in amalgamation, boundary simplification and elimination of small details.

A

```
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0
0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 0 0 0 0 1 0 0
0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0
0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0
0 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0
0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 1 1 1 1 1 1 1 0 1 0 0 0
0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0
0 0 1 0 0 0 1 1 1 1 1 1 0 0 0 0
0 0 0 0 0 0 1 1 1 1 1 1 1 1 0 0
0 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

C = erosion of *A* by *B*

```
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0
0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0
0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0
0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0
0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0
0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

D= dilation of *C* by *B*

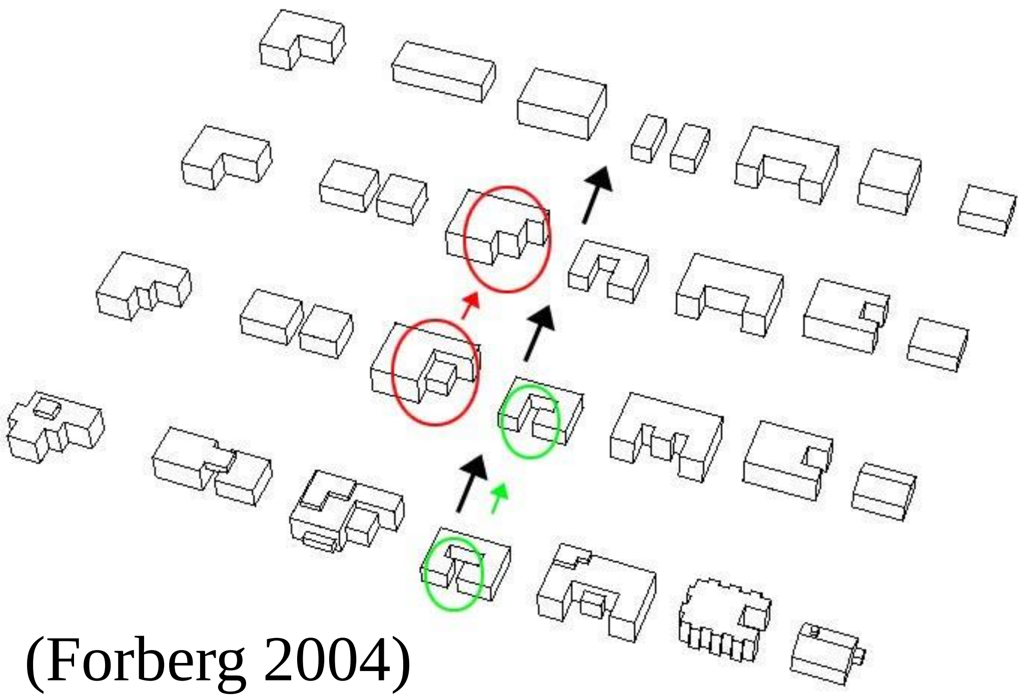
```
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0
0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 0
0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 0
0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0
0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0
0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0
0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0
0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0
0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0
0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

$$B = \begin{matrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{matrix}$$

First erosion, then dilation results in boundary simplification, elimination of small details and bridges.

3D generalisation

- Mostly for buildings

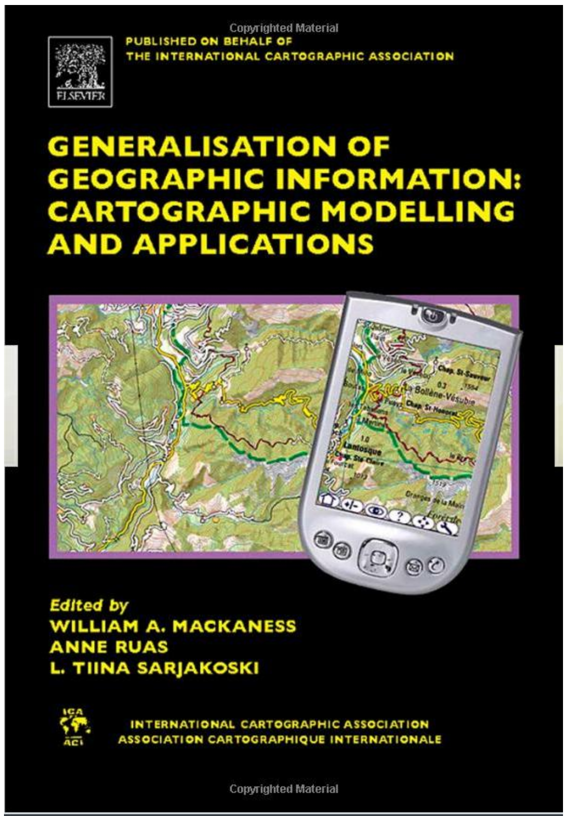


(Forberg 2004)

Where next

- Many algorithms have been implemented
- Not so many are available for use (especially contextual ones)
- The key is to combine them appropriately

- We need to make our algorithms more accessible / reusable
- We need to describe them using a common vocabulary
- … and get on with the more exciting task of combining them to deliver new innovative maps/data



Read more on this topic

Chapter 3
A Synoptic View of
Genealisation Operators
By N. Regnauld, R.B. McMaster

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