ICA Tutorial on Generalisation & Multiple Representation

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Lecture 3 : Approaches to modelling the generalisation process (30 mins)

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Overview

1. Models for the generalisation process
   - condition-action modelling
   - human interaction modelling
   - constraint-based modelling
2. Typology of constraints
3. Mathematical methods for constraint-based modelling
   - combinatorial optimization
   - continuous optimization
   - agents

MODELS FOR THE GENERALISATION PROCESS

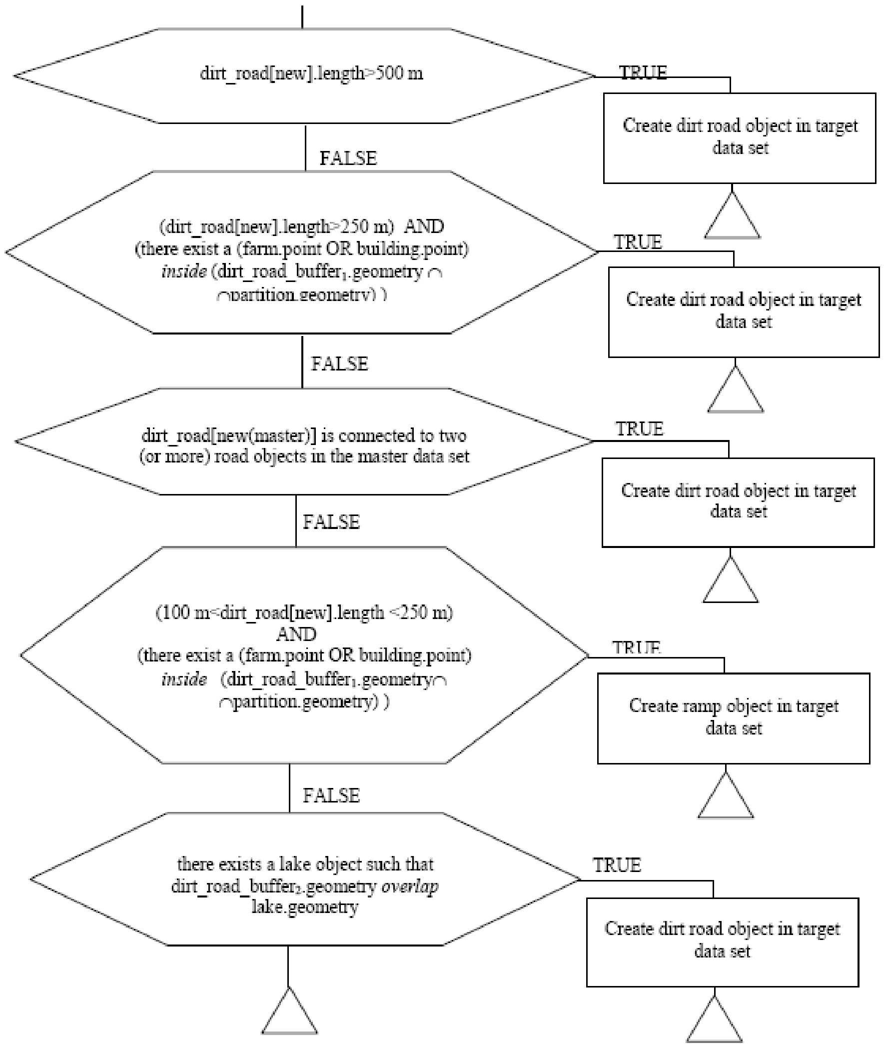
Condition-action modelling

if (objectType == *major road*)
then simplify the road using Douglas-Peucker's algorithm with a threshold value of 10 m.
if (objectType == *minor road*)
then remove the road object.
if (objectType == *building* and area $> 80\ m^2$)
then represent the building as a point object (using the gravity point of the original corner points).

if (objectType == *building* and area $< 80\ m^2$)
then remove the building object.
if (distance between object *A* (objectType == *building*) and object *B* (any object represented with a line) < 10 m)
then move object *A* in a perpendicular direction from the line object *B* so that the distance is ≥ 10 m.

Harrie and Weibel, 2007

Rules stated in flow charts



Harrie and Hellström, 1999

Condition-action modelling

- Used in rule-based systems (expert system)
- Used in several research and commercial software from the 1990s and onwards
- Based on a sequential approach

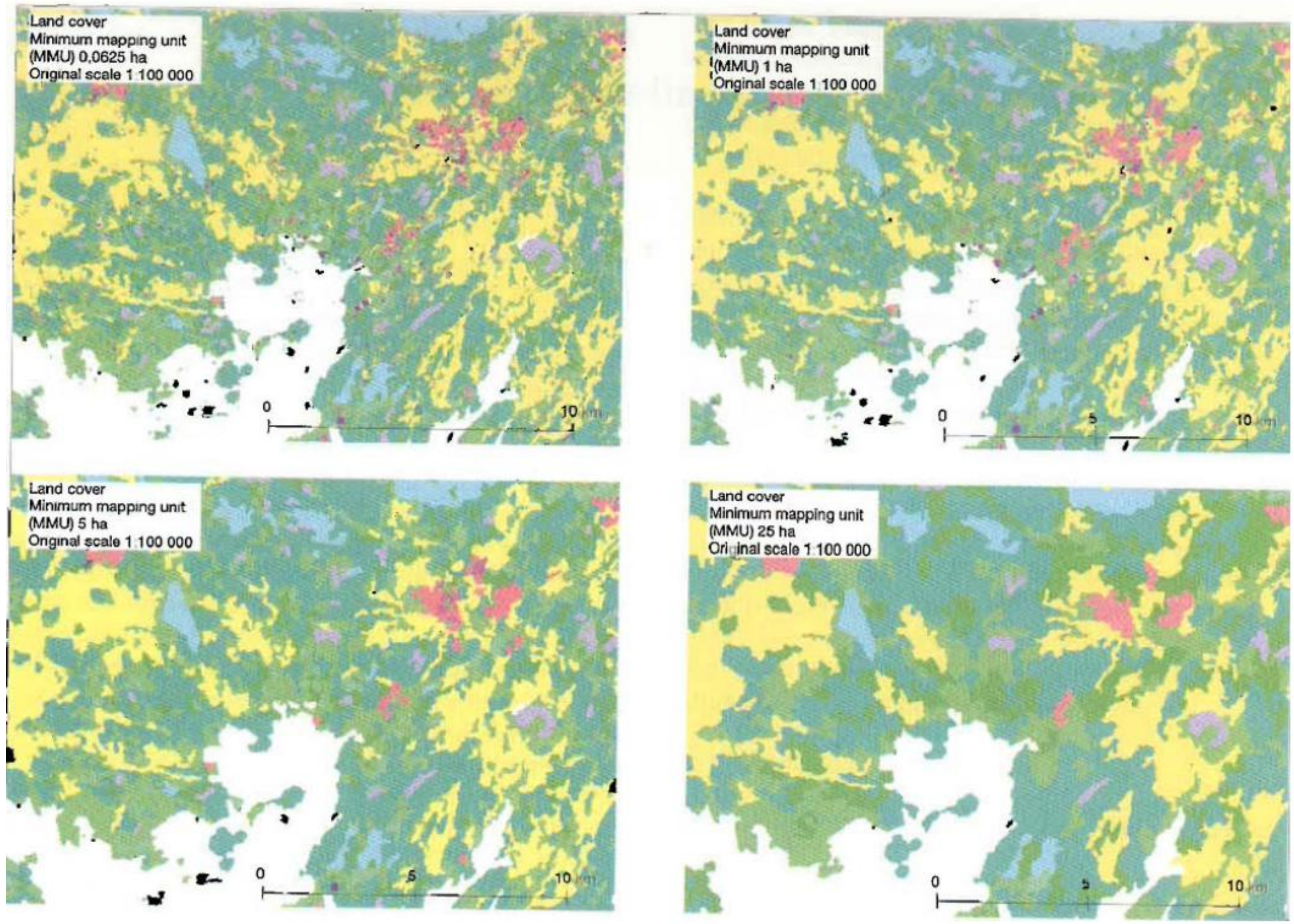
Model generalisation

Selection → Aggregation → Collapse → Simplification

Fine tuning

Exaggeration → Smoothing → Displacement

Example of result of con.-act. modelling



Jaakola, 1997

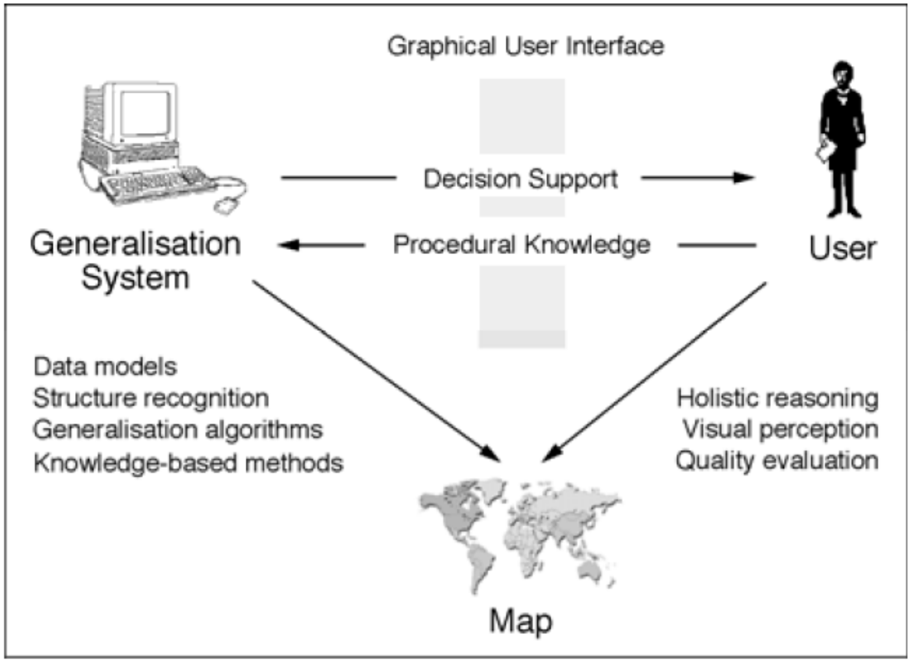
Objections against con.-act. modelling

- Knowledge acquisition bottleneck

  - hard to formalise cartographic rules
- It is hard to formalise all required rules for all possible cases; the number of rules get too large
- The rules are in conflict with each other which is not solved good in a sequential approach

Human interaction modelling

- Computers should do the repetitive tasks and humans should do the advanced reasoning
- Sometimes denoted: amplified intelligence



Weibel, 1991

Implementation of human int. modelling

- Simple human interaction modelling is found in interactive commercial systems.
- A full amplified intelligence has never been truly implemented.

Constraint-based modelling

- Generalised map should satisfy constraints
- Example of constraints

- Major road objects should be smooth and have a level of detail of about 10 meters;
- Minor road should not be represented in the map;
- Building objects with an area larger than 80 m^2 should be represented with a point symbol;
- The building point should not be further away than 10 m from the gravity point of the original corner points;
- Building with an area less than 80 m^2 should not be represented in the map;
- The closest distance between a building object and any other object should be at least 10 meters.

- Constraint-based modelling try to find a solution that adhere as good as possible to the constraints

Rule versus constraints

Condition-action (rule)

- Describe the process
  - what should be done
- Advantages:
  - intuitive
  - guidance
- Disadvantages
  - partially contradictory
  - sequence of rules are important
  - restrict the number of possible solutions (often different generalisation operations can solve the same problem)

Pure constraint

- Describe the results
  - what should be obtained
- Advantages
  - flexible
  - separation conflict analysis & solution
- Disadvantages
  - large number of constraints has to be specified
  - specification of preservation constraints is difficult (especially for patterns of objects)

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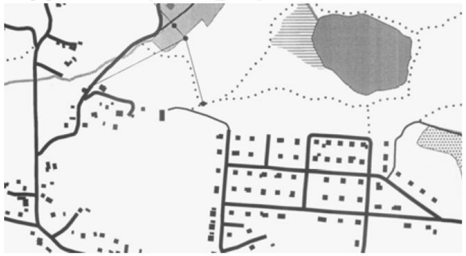
Why constraints instead of rules I

condition-action (rules) versus constraint based approaches:

- separation of situation description (conflict analysis) and generalisation action (conflict solution) are more flexible
- different generalisation operation can solve same generalisation task → constraints enable application of more than one action
- in manual generalisation nobody ask about the applied generalisation, only the final state is evaluated
- rule-based systems can become complex and non-configurable
- rules cause problems if contradictory

Why constraints instead of rules II

- Constraints enable an optimisation approach. That is, the optimal solution according to all of the constraints are found.



Selection
Aggregation
Smoothing
Exaggeration
Simplification
Displacement

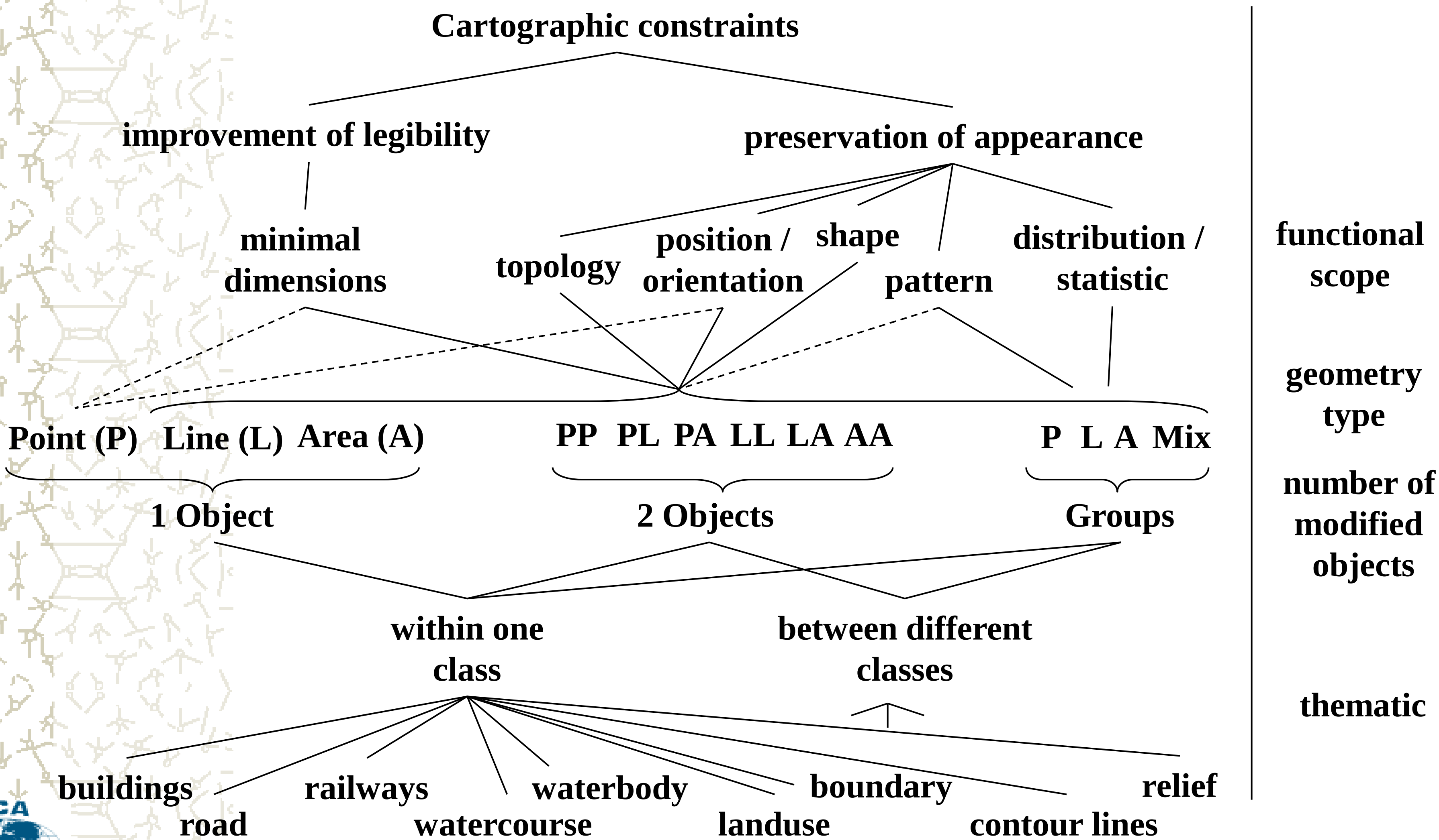
TYPOLOGY OF CONSTRAINTS

Typology of constraints

	Individual objects	Group of objects	Requirements
Position	X (absolute)	X(relative)	Preservation
Metric	X		Preservation
Topological		X	Preservation
Shape	X		Preservation
Structural		X	Preservation
Functional	X	X	Preservation
Legibility	x	X	Readibility

Ruas and Plazanet (1997)

Constraint typology

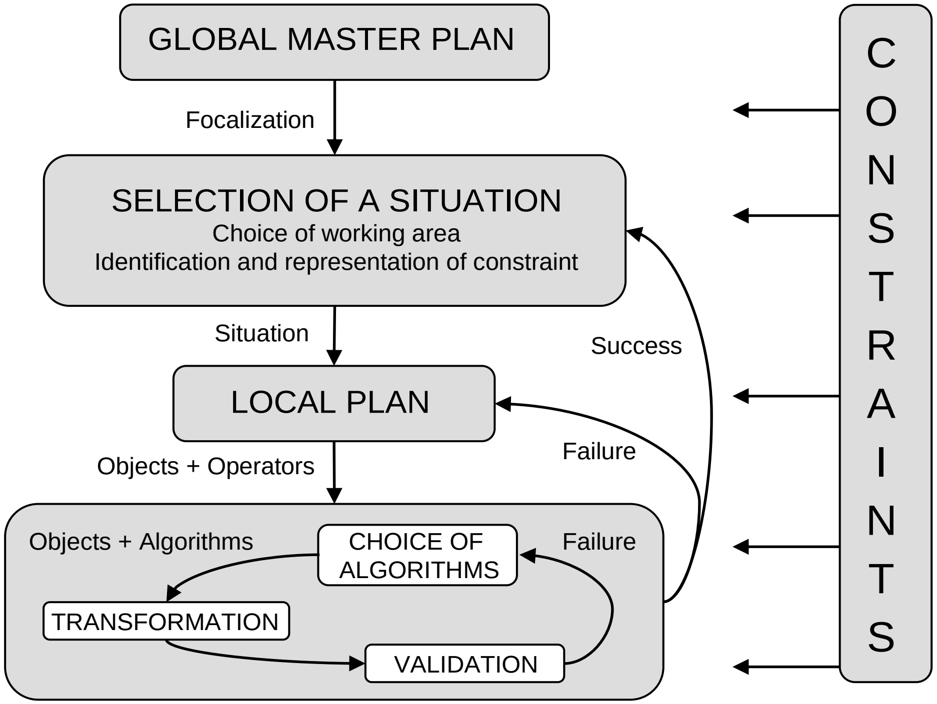


Schmidt and Burghardt, 2008

MATHEMATICAL METHODS FOR CONSTRAINT-BASED MODELLING

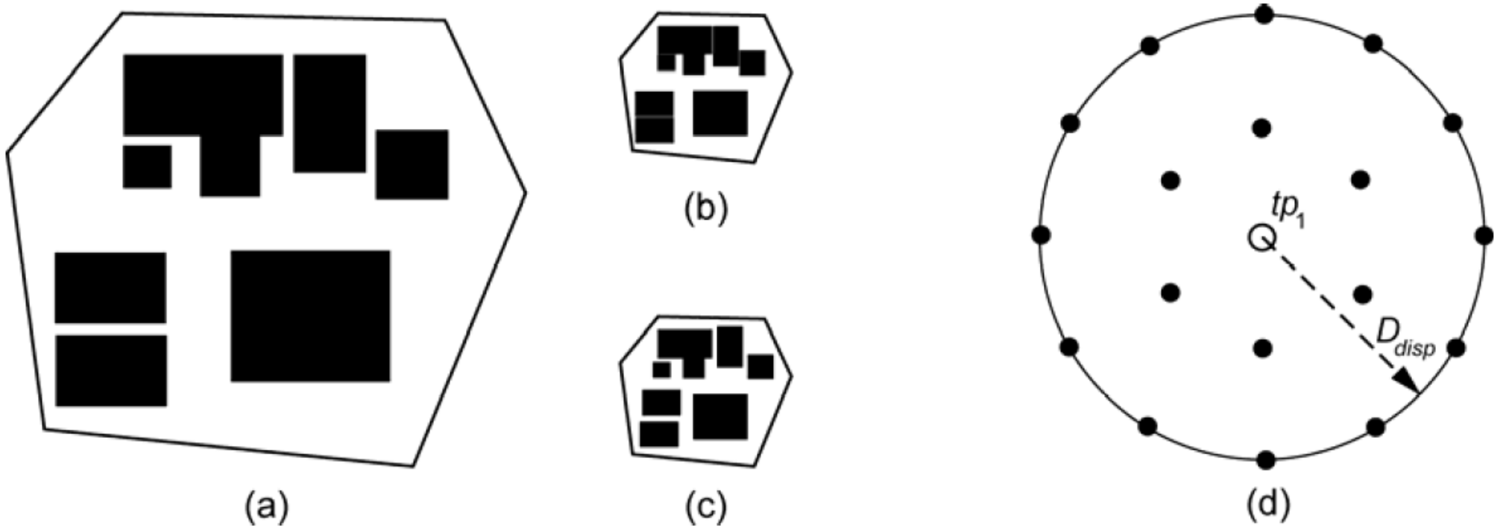
- early framework
- combinatorial optimisation
- continuous optimisation
- agent

Early framework using constraints



Generalisation process model with the utilisation of constraints (Ruas and Plazanet, 1996)

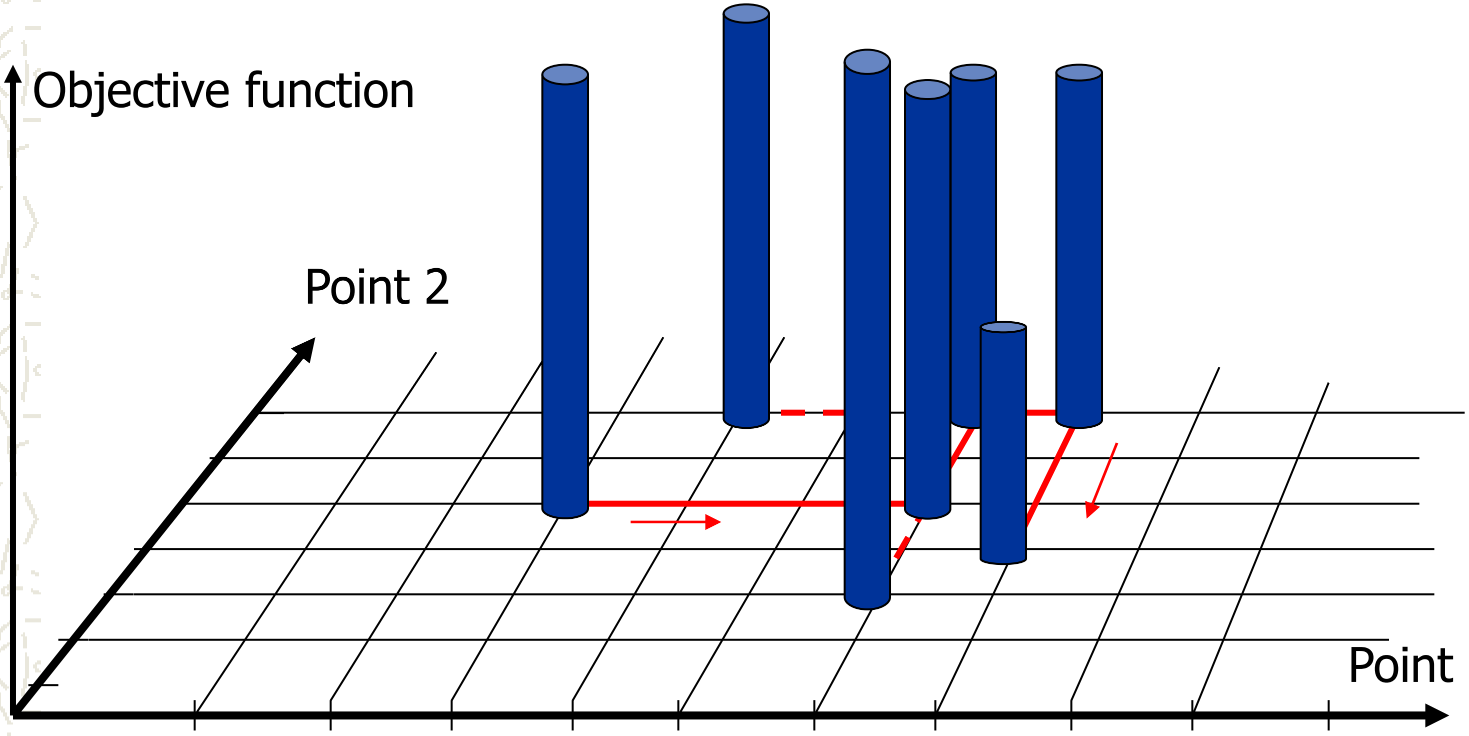
Combinatorial optimisation



Ware and Jones, 1991

Objective function = f(positions of points/objects) where f is a function that incorporates the constraints

Finding optimal solution



Possible placment of point 1

Methods used for combinatorial optimization

- Steepest gradient

  - Just search in the direction of better solutions. Can be trapped in local minima.

- Simulated annealing

  - Includes a statistical possibility to escape from local minima to find the global minima.

- Ant colony optimization

  - Based on studying earlier success (where these success are modelled using artificial pheromone trails).

Implementation of combinatorial optimization

- Often used in commercial label placement programs
- Several research prototype systems exist
- Have started to emerge in commercial systems for generalisation

Continuous optimisation

(1) Define the constraints of the generalised map.

↓

(2) Formulate the constraints analytically as functions of point locations (measures).

↓

(3) Use the measures to form an objective function.

↓

(4) Find the minimum of the objective function using a standard mathematical technique.

↓

(5) Generalise the map using the point locations found by the optimisation process.

That is, all the constraints are formulated as linear equations of point movements. Then the solution that best satisfy the constraints are found.

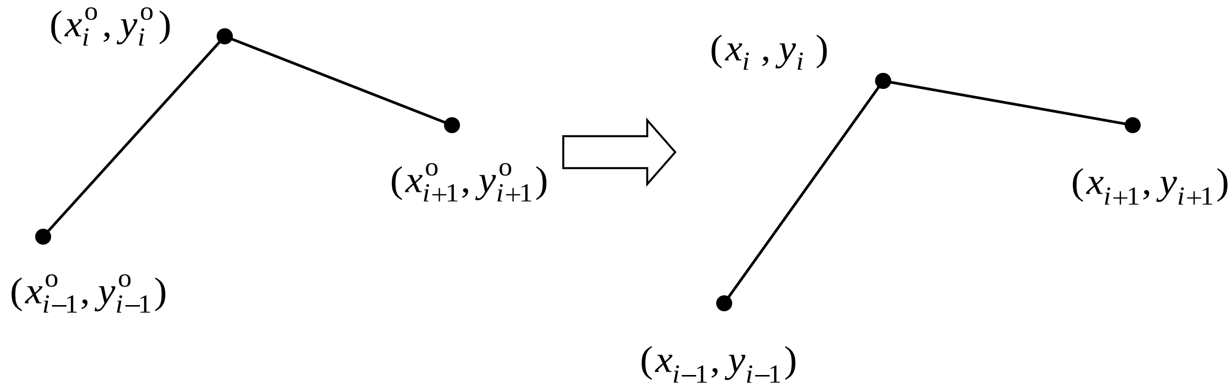
Harrie and Weibel, 2007

Methods used for continuous optimization

- Snakes
- Least squares
- Finite element methods

The way the equations are set up (and relationships modelled) are somewhat different in these methods. But the general structure is the same: the cartographic points are moved to satisfy constraints as good as possible.

Example of linear equation of angle preservation



$$\left((y_i^{o} - y_{i+1}^{o}) / \left(\|\mathbf{u}\| \cdot \|\mathbf{w}\|\right)\right) \cdot \Delta x_{i-1} + \left((-x_i^{o} + x_{i+1}^{o}) / \left(\|\mathbf{u}\| \cdot \|\mathbf{w}\|\right)\right) \cdot \Delta y_{i-1} +$$

$$+ \left((-y_{i-1}^{o} + y_{i+1}^{o}) / \left(\|\mathbf{u}\| \cdot \|\mathbf{w}\|\right)\right) \cdot \Delta x_i + \left((x_{i-1}^{o} - x_{i+1}^{o}) / \left(\|\mathbf{u}\| \cdot \|\mathbf{w}\|\right)\right) \cdot \Delta y_i +$$

$$+ \left((y_{i-1}^{o} - y_i^{o}) / \left(\|\mathbf{u}\| \cdot \|\mathbf{w}\|\right)\right) \cdot \Delta x_{i+1} + \left((-x_{i-1}^{o} + x_i^{o}) / \left(\|\mathbf{u}\| \cdot \|\mathbf{w}\|\right)\right) \cdot \Delta y_{i+1} = 0 \quad .$$

where **u** and **w** are the length of the segments.

Harrie, 1999

Least squares solution of the linear equations

Create an (overdetermined) linear equation system where the unknowns (**x**) are the point movements:

$$\mathbf{Ax} = \mathbf{l} + \mathbf{v}$$

The equation has the least square solution:

$$(\mathbf{A}^t\mathbf{PA})\mathbf{x} = \mathbf{A}^t\mathbf{Pl}$$

Implementation of continuous optimization

- There are several research prototype
- Commercial LSA product from Hanover
- Have started to be evaluated for map production

Comparison of constraint-bas. methods

- Combinatorial optimization

+ Good when there are a fixed number of solutions. Typical examples are text setting and schematic maps, but also good for e.g. displacement.

- Many generalisation tasks (e.g. aggregation) require a too large search space which makes combinatorial optimization impractical.

- Continuous optimization

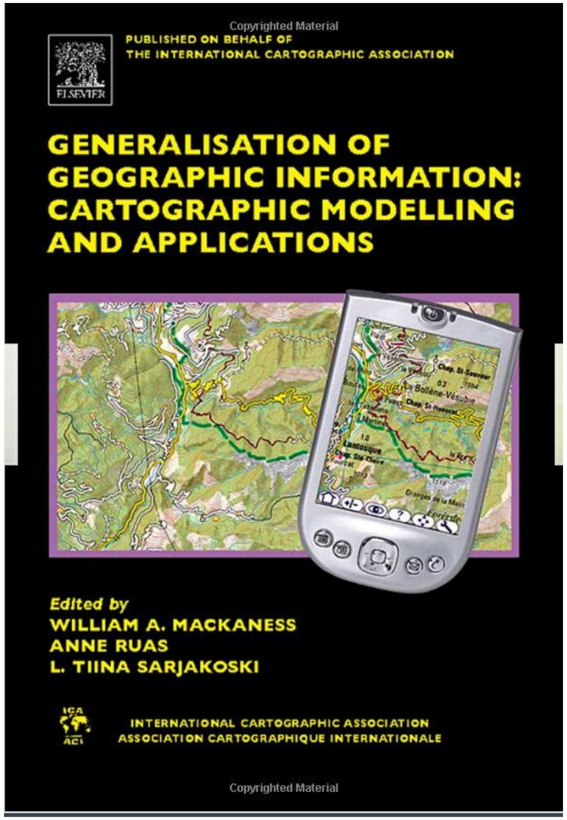
+ Good when the generalisation problem can be defined as a rubber sheet transformation.

- Cannot handle aggregation, selection, etc.

- Agent-based systems (described in later presentation)

+ Flexible method that can handle most situations in the generalisation process. Can also integrate other methods.

- Complicated. To solve specific tasks other methods can provide at least as good result.



Read more on this topic

Chapter 4
Modelling the Overall Process of Generalisation by Harrie and Weibel

Questions?