Investigations on Cartographic Constraint Formalisation

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Outline

- Introduction – EuroSDR-project “state-of-the-art” of commercially available generalisation software
- Typology of cartographic constraints
- Comparison of different NMA specifications
- Constraint formalisation
- Evaluation of generalisation solutions
Introduction

• EuroSDR-project objectives:
  - studying the state-of-the-art of commercially available generalisation software
    “to establish by a small set of controlled tests the state-of-the-art in generalisation, particularly with reference to … map production, … to inform both potential users and ongoing research”
    + software suppliers
  - focus is set on the generalisation of a complete topographic data sets at scales larger than 1:50k

• Timetable (start of the project Oct 2006)
  - testing from 1st of June till 1st of Nov 2007
Introduction

- Definition of case studies covering areas in different countries
- Preparation of test data based on simplified data models
- Specification of cartographic requirements (*constraints*) for the target maps

ICC data set (costal area)  TDK data set (rural area)  OSUK data set (urban area)
The usage of cartographic constraints in automated generalisation

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

Constraint definition from AGENT

The effect of constraints is to reduce the number of possible results of a process, while at the same time increasing the proportion of acceptable ones.

- **Cartographic constraints** (arising from characteristics of data and map specifications)
- **Process constraints** (arising from resource limitations and workflows)

the constraints template were filled out by the four NMA specifically for the test cases of the EuroSDR project, i.e. the constraints that were generated are not meant to offer a complete description of cartographic generalisation output
Constraint typology

Cartographic constraints

- improvement of legibility
- preservation of appearance
  - topology
    - position/orientation
    - shape
    - pattern
    - distribution/ statistic
  - number of modified objects
    - buildings
    - railways
    - waterbody
    - landuse
    - boundary
    - relief
    - contour lines

constraint type
geometry type
number of modified objects
thematic
Constraint typology

Cartographic constraints

- improvement of legibility
- preservation of appearance

- minimal dimensions
- topology
- position / orientation
- shape
- pattern
- distribution / statistic

- number of modified objects
- constraint type

- geometry type
- number of modified objects
- thematic

1 Object

- within one class
- between different classes

- buildings
- road
- railways
- waterbody
- landuse
- boundary
- contour lines

2 Objects

- Groups

Point (P) Line (L) Area (A)

PP PL PA LL LA AA P L F Mix
Comparison of NMA specifications

Frequency distribution according to the constraint type:

- Constraint type of preserving minimal dimensions plays the most important role in all specifications.
-Statistic and distribution constraints are rare.
-Number of constraints differs strongly between the different specifications.

<table>
<thead>
<tr>
<th>Constraint Type</th>
<th>ICC</th>
<th>IGN</th>
<th>TDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal dimensions</td>
<td>79</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>Removal / emphasize</td>
<td>26</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>Topology</td>
<td>14</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Position / orientation</td>
<td>6</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Shape</td>
<td>6</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Pattern</td>
<td>10</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Distribution / statistics</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>
Comparison of NMA specifications

Frequency distribution according to the number of modified objects:

- Most of the constraints refer to one object whereas fewer constraints are defined for two or more objects.
- Constraints for group objects often refer to building themes.

<table>
<thead>
<tr>
<th></th>
<th>ICC</th>
<th>IGN</th>
<th>TDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constraints on one object</td>
<td>98</td>
<td>32</td>
<td>23</td>
</tr>
<tr>
<td>Constraints on two objects</td>
<td>27</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Constraints on a group of objects</td>
<td>30</td>
<td>12</td>
<td>2</td>
</tr>
</tbody>
</table>
Comparison of NMA specifications

Frequency distribution according to the thematic scope:

- The large amount of constraints on building themes as well as on road themes is noticeable
- Boundary themes doesn’t exist in the compared constraint specifications (exception: OSUK constraint specifications)

<table>
<thead>
<tr>
<th>Theme</th>
<th>ICC</th>
<th>IGN</th>
<th>TDK</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>49</td>
<td>36</td>
<td>12</td>
<td>97</td>
</tr>
<tr>
<td>Road</td>
<td>35</td>
<td>15</td>
<td>21</td>
<td>71</td>
</tr>
<tr>
<td>Railways</td>
<td>Doesn’t exist</td>
<td>Doesn’t exist</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Watercourse</td>
<td>23</td>
<td>6</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Waterbody</td>
<td>26</td>
<td>6</td>
<td>2</td>
<td>34</td>
</tr>
<tr>
<td>Landuse/Landcover</td>
<td>32</td>
<td>6</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>Contour lines</td>
<td>16</td>
<td>2</td>
<td>Doesn’t exist</td>
<td>18</td>
</tr>
<tr>
<td>Boundary</td>
<td>Doesn’t exist</td>
<td>Doesn’t exist</td>
<td>Doesn’t exist</td>
<td>0</td>
</tr>
<tr>
<td>Relief</td>
<td>2</td>
<td>2</td>
<td>Doesn’t exist</td>
<td>4</td>
</tr>
</tbody>
</table>
Comparison of NMA specifications

Illustration of frequency distribution based on the number of defined constraints:

- topology (27)
- position/orientation (13)
- shape (13)
- pattern (18)
- distribution/statistics (10)
- removal/emphasize (58)
- two objects (57)
- several objects (44)
- between different classes (35)
- watercourse (40)
- waterbody (34)
- railway (4)
- boundary (0)
- contour line/relief (22)
- landuse/landcover (50)
Comparison of NMA specifications

What are the reasons for the irregular frequency distribution of constraints?

Possible reasons:

- Number of constraints defined is proportional to number and complexity of map objects (effort needed on manual generalisation)
- Extend of scientific research (e.g. generalisation of building features is frequently object of interest)
- Incomplete handling, because focus was set only on specific data sets
Comparison of NMA specifications

Illustration of frequency distribution based on the number of defined objects provided by ICC:

minimal dimensions

one object

within a class

between different classes

watercourse
waterbody
building
road
railway
boundary
contour line/relief
landuse/landcover
Comparison of NMA specifications

Illustration of frequency distribution based on the number of defined objects provided by IGN:

minimal dimensions

one object

within a class

two objects

several objects

between different classes

watercourse

waterbody

building

road

railway

boundary

contour line/relief

landuse/landcover

removal/emphasize

topology

position/orientation

shape

pattern

distribution/statistics
Comparison of NMA specifications

Illustration of frequency distribution based on the number of defined objects provided by TDK:

- minimal dimensions
- removal/emphasize
- one object (23)
- two objects (24)
- within a class (33)
- between different classes (6)

Categories:
- watercourse:5
- waterbody:2
- building:12
- road:21
- railway:4
- boundary:0
- contour line/relief:7
- landuse/landcover:12
Harmonisation

Reason for harmonisation:
simplify test and evaluation procedures with the four different test data sets and the corresponding constraint specifications

- Number and granularity of specified thematic classes varied, e.g.
  ICC had a more detailed data model at the beginning → more constraints
- Different handlings of unimportant objects (model generalisation) → more “removal” constraints
- Constraint template itself
- Classification of constraints into two categories: specific / generic
- **Generic** constraints (within the project!) could be derived by comparing the different NMA constraint specifications
### Formalisation

<table>
<thead>
<tr>
<th>NMA</th>
<th>Class</th>
<th>Condition for object being concerned with constraint</th>
<th>Constraint property</th>
<th>Condition depends on initial value?</th>
<th>Condition to be respected</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGN</td>
<td>Building</td>
<td>Symbolisation ≠ 'Town hall' and initial_area &lt; 30.0 terrain m²</td>
<td></td>
<td></td>
<td>Building should not appear in DCM</td>
</tr>
<tr>
<td>OSUK</td>
<td>Building</td>
<td>Size inferior to 0.16mm²</td>
<td>Size</td>
<td>No</td>
<td>Not displayed</td>
</tr>
<tr>
<td>ICC</td>
<td>Building</td>
<td>Isolated</td>
<td>Minimum area including holes</td>
<td>No</td>
<td>Maintain and area &gt; 400 m²</td>
</tr>
<tr>
<td>TDK</td>
<td>Building</td>
<td>type_of_building ≠ “list 1” (see Comments column)</td>
<td>Length (edge or diameter)</td>
<td></td>
<td>Instance should not appear in DCM if length (edge or diameter) &lt; 20 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generic Constraint ID</th>
<th>Geometry type</th>
<th>Condition for object being concerned with constraint</th>
<th>Constraint property</th>
<th>Condition depends on initial value?</th>
<th>Condition to be respected</th>
</tr>
</thead>
<tbody>
<tr>
<td>EuroSDR 1-1</td>
<td>Polygon</td>
<td>Area</td>
<td>No</td>
<td>target area &gt; x map mm²</td>
<td></td>
</tr>
</tbody>
</table>
## Degree of Formalisation

### Concrete formalisation

<table>
<thead>
<tr>
<th>Generic Constraint ID</th>
<th>Geometry type</th>
<th>Condition for object being concerned with constraint</th>
<th>Constraint property</th>
<th>Condition depends on initial value?</th>
<th>Condition to be respected</th>
</tr>
</thead>
<tbody>
<tr>
<td>EuroSDR 1-16</td>
<td>Line and Polygon</td>
<td>Initially, no self-intersection</td>
<td>Intersection</td>
<td>Yes</td>
<td>No self-intersection must be created</td>
</tr>
<tr>
<td>EuroSDR 1-10</td>
<td>Polygon</td>
<td>Area of protrusion</td>
<td>No</td>
<td></td>
<td>target area &gt; x map mm²</td>
</tr>
</tbody>
</table>

### Imprecise formalisation

<table>
<thead>
<tr>
<th>Generic Constraint ID</th>
<th>Geometry type</th>
<th>Condition for object being concerned with constraint</th>
<th>Constraint property</th>
<th>Condition depends on initial value?</th>
<th>Condition to be respected</th>
</tr>
</thead>
<tbody>
<tr>
<td>EuroSDR 1-1</td>
<td>Polygon</td>
<td>1:n relation (amalgamation)</td>
<td>General shape</td>
<td>Yes</td>
<td>target shape should be similar to initial shape</td>
</tr>
</tbody>
</table>
Process active vs. restrictive (condition-action vs. constrained based)

Process active

Condition (constraint) + generalisation action \{ rule \}

Advantages
- guidance
- close to manual generalisation

Disadvantages
- partially contradictory
- sequence of rules are important
- restrict the number of possible solutions (often different generalisation operations can solve the same problem)
- focus on legibility constraints

Process restrictive

Advantages
- flexible
- separation of conflict analysis and conflict solution

Disadvantages
- a large number of constraints has to be specified
- specification of preservation constraints is difficult (if there is the expectation that the generalisation will not effect a particular area or feature class)
Evaluation

Source data set

Specs of target data set

Evaluation I

Result 1

Evaluation II

Result 2

Evaluation III

Evaluation III
Evaluation I (first prototype)

- data and symbolisation loading
- constraint selection
- parameter setting

implemented by Stefan Schmid and Moritz Wittensöldner
Evaluation I (first prototype)

Implementated by Stefan Schmid and Moritz Wittensöldner

Output of evaluation values

<table>
<thead>
<tr>
<th>ID</th>
<th>Constraint/Operator Evaluation</th>
<th>Constraint/Operator/Similarity</th>
<th>Severity</th>
<th>Old</th>
<th>Current</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>157</td>
<td>0.97</td>
<td>0.97</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
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<td>1.00</td>
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<td>-0.00</td>
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<td>-0.00</td>
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<td>-0.00</td>
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<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>-0.00</td>
</tr>
</tbody>
</table>

Workshop of the ICA Commission on Generalisation and Multiple Representation, Moscow 19.08.2007 / 24
Evaluation I (first prototype)

implemented by Stefan Schmid and Moritz Wittensöldner

Automatic data selection
Conclusion

• Comparison of constraint formalisation carried out by four NMA within the EuroSDR project
• Constraint typology was used to categorise and visualise the frequency distribution of specified constraint
  - most of the defined constraints refer to \textit{minimal dimensions} of \textit{one object} of type \textit{line (L)} or \textit{area (A)} within \textit{one class} of type \textit{building} or \textit{road}
  - Question: Is this a typical distribution or only valid for the test data?
• Formalisation:
  - constraint template was specified, but the degree of formalisation varies
  - a common syntax for constraint specifications would be useful
  - two direction of constraint specification: process active (legibility constraints) vs. process restrictive (preservation constraints)
• Evaluation
  - three types of evaluation will be carried out
  - a prototype for evaluation (I) of generalised data sets against constraint specification will be available
Successful testing for the EuroSDR team!
Constraint-based approaches and condition-action modelling

- separation of situation description (conflict analysis) and generalisation action (conflict solution) are more flexible
- often different generalisation operation can solve the same generalisation task
  → constraints enable the 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
What is a constraint?

```plaintext
If ( condition() ) {
  ... // action
}
```