A typology of multi-scale mapping operators

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The ScaleMaster diagram is a schematic for organizing scale-dependent map designs for multi-scale projects (Brewer and Buttenfield 2007; Brewer et al. 2007). A ScaleMaster diagram is comprised of a series of decision points that mark the scales at which the map design needs modification in order to maintain legibility and that note the accompanying design alterations implemented at these scales. This poster reports our efforts to produce a typology of available design alterations, or multi-scale mapping operators, for inclusion in the ScaleMaster.org site, an interactive, web-based tool for easily creating ScaleMaster diagrams. We purposefully distinguish multi-scale mapping operators, which include any action that maintains map legibility when changing scale, from generalization operators, which are specific to those actions that meaningfully reduce detail in the geospatial data and commonly imply an alteration of feature geometry.

A logical starting point for a typology of multi-scale mapping operators is a review of generalization typologies offered in the cartographic literature. Such typologies commonly organize the basic, micro-level units by broader, macro-level categories. The provided macro-level distinctions vary greatly, including pre-processing versus generalization (Robinson et al. 1978), attribute versus spatial transformations (McMaster and Shea 1992), spatial dimensionality (McMaster and Monmonier 1989; Monmonier 1996; Li 2007), and model versus cartographic generalization (Weibel and Dutton 1999; Foerster et al. 2007). Despite this inconsistency in macro-level categorization, only operators or algorithms are used as the micro-level unit. An operator is an abstract or generic description of an action or modification, while an algorithm is a particular programmatic implementation of an operator (Regnauld and McMaster 2007). Exhaustive classifications of generalization algorithms are provided by the AGENT report (1999) and Li (2007). However, most generalization typologies use
the operator as the micro-level unit because (1) many algorithms implement
the same operator, multiplying the number of entities in the typology, (2)
the naming of algorithms is often software dependent, complicating the
identification of unique micro-level units, and (3) typologies using the
algorithm as the micro-level unit quickly become out-of-date as new
algorithms are developed. For these reasons, we used operators as the
micro-level unit in our multi-scale mapping typology.

A comparison of noteworthy generalization typologies using operators as
the micro-level unit is included on the left portion of Figure 1. The first
three typologies included in Figure 1 (Raisz 1962; Steward 1974; and
Robinson et al. 1978) illustrate that early scholars viewed generalization as
more than a modification of vector geometry. However, many of the
operator typologies offered since the late 1980s focus upon the role of
generalization alteratons to reduce detail when transitioning to a smaller scale
(e.g., DeLucia and Black 1987; McMaster and Shea 1992; Foerster et al.
2007). Due to the emphasis on geometry in the generalization literature,
limited attention has been given to the maintenance of legibility in multi-
scale mapping through the reorganization of displayed map content or the
adjustment of feature symbology. Brewer and Buttenfield (2007) contend
that alterations of the content or symbology can result in an equally legible
representation at a reduced scale, often requiring a smaller required
workload for the cartographer or higher computational efficiency for
automation. Brewer et al. (2007) identify a large set of possible non-
geometry multi-scale mapping operators (right portion of Figure 1),
drawing heavily on Bertin’s (1983) visual variables.

The ScaleMaster multi-scale mapping typology, provided in the right
portion of Figure 1, organizes operators into three macro-level categories:
(1) content, (2) geometry, and (3) symbology. The content macro-level
category, following Monmonier’s (1996) concept of ‘content
generalization’ and combining Robinson et al’s (1978) ‘selection’ and
‘classification’, is defined as the set of operators that revise (i.e., add or
eliminate map layers) or reorganize (i.e., reclassify or reorder map layers) a
portion or all of the content to be mapped in order to maintain legibility
when changing scale. The geometry macro-level category, following
Regnauld and McMaster’s (2007) concept of ‘fundamental geometric
generalization operators’, is defined as the set of operators that modify the
spatial geometry of mapped features to maintain legibility when changing
scale. The symbology macro-level category, following Robinson et al.’s
(1978) concept of symbology, is defined as the set of operators that alter
the graphic encoding of mapped features to maintain legibility when
changing scale. Table 1 provides a definition of each multi-scale mapping operator in the ScaleMaster typology. The poster will provide a historical synopsis of each operator and full-color before-and-after illustrations.

Figures/Tables
Fig. 1: (left) Generalization operators suggested in the cartographic literature. The dark grey represents the first appearance of a generalization operator in the literature and the light grey represents is subsequent mention in other typologies. Inconsistencies in the usage of terms are marked with footnotes. (right) The ScaleMaster.org typology of multi-scale mapping operators. B represents the macro-level categories of content, geometry, and symbology for the ScaleMaster typology.

<table>
<thead>
<tr>
<th>operator</th>
<th>definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>content</strong></td>
<td></td>
</tr>
<tr>
<td>add</td>
<td>insertion of features</td>
</tr>
<tr>
<td>eliminate</td>
<td>removal of features</td>
</tr>
<tr>
<td>reclassify</td>
<td>revision to the grouping of features based on their attributes</td>
</tr>
<tr>
<td>reorder</td>
<td>adjustment to the stacking position of features relative to others</td>
</tr>
<tr>
<td><strong>geometry</strong></td>
<td></td>
</tr>
<tr>
<td>aggregate</td>
<td>reduction in complexity of many related features by replacing them with a representative feature of increased dimensionality</td>
</tr>
<tr>
<td>collapse</td>
<td>reduction in complexity of features by replacing them with a representative symbol of lower dimensionality</td>
</tr>
<tr>
<td>merge</td>
<td>reduction in complexity of many related features by replacing them with a representative map feature of equal dimensionality</td>
</tr>
<tr>
<td>displace</td>
<td>adjustment to the location of a feature to avoid coalescence with adjacent map features</td>
</tr>
<tr>
<td>exaggerate</td>
<td>amplification or adjustment to a portion of a feature to emphasize or maintain a characteristic aspect of it</td>
</tr>
<tr>
<td>simplify</td>
<td>reduction of the number of points constituting a feature</td>
</tr>
<tr>
<td>smooth</td>
<td>removal of small variations in the geometry of a feature to improve its appearance</td>
</tr>
<tr>
<td><strong>symbology</strong></td>
<td></td>
</tr>
<tr>
<td>adjust color</td>
<td>adjustment of a symbol's color to ensure legibility of the map feature or surrounding features</td>
</tr>
<tr>
<td>enhance</td>
<td>inclusion of graphic embellishments around or within a symbol without changing the underlying geometry to maintain or emphasize important characteristics of a feature's relations to other features</td>
</tr>
<tr>
<td>adjust pattern</td>
<td>substitution of a stroke or fill with one that is different in complexity without changing the underlying geometry</td>
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<tr>
<td>rotate</td>
<td>adjustment of the orientation of a symbol to maintain or emphasize its relations to other features</td>
</tr>
<tr>
<td>adjust shape</td>
<td>substitution of a symbol shape with one that is different in complexity without changing the map feature's dimensionality</td>
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<tr>
<td>adjust size</td>
<td>uniform adjustment of symbol size without changing dimensionality</td>
</tr>
<tr>
<td>adjust transparency</td>
<td>adjustment of the opacity of a symbol to improve the clarity of the feature or underlying features</td>
</tr>
<tr>
<td>typify</td>
<td>reduction in the complexity of many related map features by replacing them with a sparser, representative arrangement of the same symbols</td>
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Tab. 1: Multi-scale mapping operator definitions for the ScaleMaster.org site.
REFERENCES


