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 Monomonier 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of unique micro-level units, and (3) typologies using the algorithm as the micro-level unit quickly become out-of-date as new algorithms are developed.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 geometry alterations 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

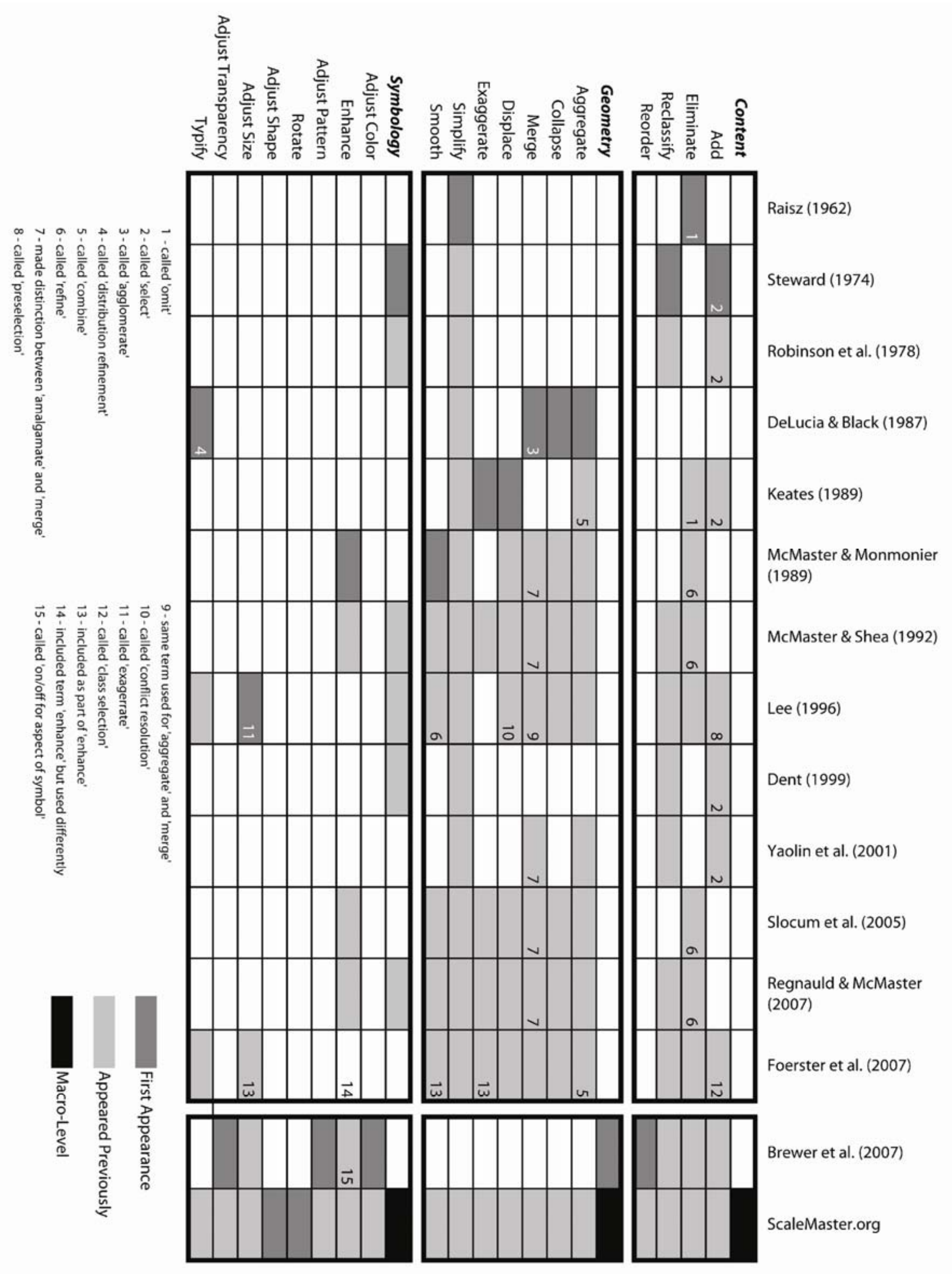

Fig. 1: **(left)** Generalization operators suggested in the cartographic literature. The dark grey represents the first appearance of a generalization operator in the literature and the light grey represents is subsequent mention in other typologies. Inconsistencies in the usage of terms are marked 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.

	operator	definition
content	add	insertion of features
	eliminate	removal of features
	reclassify	revision to the grouping of features based on their attributes
	reorder	adjustment to the stacking position of features relative to others
geometry	aggregate	reduction in complexity of many related features by replacing them with a representative feature of increased dimensionality
	collapse	reduction in complexity of features by replacing them with a representative symbol of lower dimensionality
	merge	reduction in complexity of many related features by replacing them with a representative map feature of equal dimensionality
	displace	adjustment to the location of a feature to avoid coalescence with adjacent map features
	exaggerate	amplification or adjustment to a portion of a feature to emphasize or maintain a characteristic aspect of it
	simplify	reduction of the number of points constituting a feature
	smooth	removal of small variations in the geometry of a feature to improve its appearance
symbology	adjust color	adjustment of a symbol's color to ensure legibility of the map feature or surrounding features
	enhance	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
	adjust pattern	substitution of a stroke or fill with one that is different in complexity without changing the underlying geometry
	rotate	adjustment of the orientation of a symbol to maintain or emphasize its relations to other features
	adjust shape	substitution of a symbol shape with one that is different in complexity without changing the map feature's dimensionality
	adjust size	uniform adjustment of symbol size without changing dimensionality
	adjust transparency	adjustment of the opacity of a symbol to improve the clarity of the feature or underlying features
	typify	reduction in the complexity of many related map features by replacing them with a sparser, representative arrangment of the same symbols

Tab. 1: Multi-scale mapping operator definitions for the ScaleMaster.org site.

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