CROSS-CULTURAL AND FUNDAMENTAL GENERALIZATION RULES

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Abstract

The focus of this study was the examination of cartographic knowledge, map generalization criteria in the manual production of intermediate scale topographic maps derived from larger scale topographic maps. The common map generalization criteria, i.e., cross-cultural generalization rules were examined. This examination included a determination of the applicability of use of the Japanese generalization guidelines to derive 1:50,000 scale topographic maps from 1:24,000 or 1:25,000 maps in the United States by a comparison of written generalization guidelines from Japan and the United States and the interviews who work on the generalization processes in Japan and the United States. The examination identified fifteen cross-cultural generalization rules and found significant similarities in the treatment of cultural features and implicit comparabilities of the hierarchical orders of features but in the treatment of physical features between two countries.

1. Introduction

Cartographic generalization remains one of the most intellectually and technically challenging aspects of the mapping process to be solved in order to produce successful cartographic representation. Over the decades, academic and industry researchers alike have noted the difficulties in automating the generalization process from the manual generalization procedure, which is an intellectual and manipulative activity (Shea, 1991). For the needs of more comprehensive solutions, contemporary research has sought to incorporate more knowledge into generalization procedures. This is related to the advances in the field of artificial intelligence (AI) including expert systems strategies, which are based on the assumption that human knowledge and skill can indeed be formalized and modeled as a set of rules to automate eventually the behavior of human experts (Weibel, 1991). Yet, much work lies ahead in the acquisition of cartographic knowledge from expert sources. Topographic maps have been considered as a rich source of cartographic knowledge in recent studies, which try to establish well-defined sets of rules, i.e., formalizing cartographic rules. The reasons for the popularity of topographic maps for the acquisition of knowledge are, as Buttenfield et al. (1991) suggests, "the topographic mapping process provides a standardized environment within which empirical research may be controlled" (p.892).

While map generalization involves every map to some extent, this study examines only map generalization criteria to derive 1:50,000 scale topographic maps from 1:24,000 or 25,000 scale topographic maps. This focus of study is based on the past research, which suggest that there may be common map generalization criteria in order to derive maps which have similar control factors of generalization. The control factors considered here are scale, graphic legibility, quality of data of source maps, technical reproduction capabilities of mapping institutions and purpose of maps. Are there common generalization rules that can be used in the compilation of comparable intermediate scale maps with similar objectives, scales, and data sources? Which generalization rules in terms of procedures and types of features are comparable in different countries and which rules are not? To what extent, can manual map generalization criteria be objectively defined?

2. Cartographic Knowledge

A rule-based approach for map generalization implies that human knowledge of the generalization process can be formalized into a chain of reasoning paths, each leading to a particular decision or procedure for generalization to take place (Muller, 1991).

There are three types of knowledge for effectively implementing rule-based systems designed to perform generalization: geometrical knowledge, structural knowledge, and procedural knowledge (Armstrong, 1991). Geometrical knowledge is where size, form, distance and connectedness are assessed. Structural knowledge is where the underlying generating processes which gave rise to a phenomenon are analyzed. Procedural knowledge is where appropriate tools (including simplification, selection and classification) are identified (Muller, 1991). Knowledge is also classified into two types: 1) knowledge involves decision making process and mechanisms which lead to the identification of execution tasks, 2) knowledge for execution of procedures for map generalization, e.g., parameters of simplification algorithms to specific cartographic features. The first type of knowledge is what McMaster and Shea (1988) identifies 'why' and 'when' to generalize while the second type knowledge is 'how' to generalize. Much of the existing body of map generalization research has been concerned with the second type of knowledge, i.e., the problems of parameters for execution of generalization procedure.

Production systems are commonly used to represent knowledge for rule-based systems (Shea, 1991, Lanter, 1992). Knowledge expressed as production rules takes the form of a set of stimulus-response pairs and expressed as:

IF <condition>: THEN <action>

Thus, every reasoning path consists of information involving interdependencies *and trade-offs which* must be made in order to arrive at a solution. The advantages of the use of production rules in knowledge representation of rules are moduality, uniformity, flexibility, preciseness and naturalness (Lanter, 1992).

Since production rules are the most obvious way to describe generalization guidelines, common to many studies such as Mark (1991) and Muller (1991), who try to extract knowledge from existing manual map generalization rules in the attempt to build models of knowledge-based systems, use production rules to represent knowledge of manual generalization rules. In those studies, topographic maps have been considered as a rich source of cartographic knowledge.

2.1 Previous Studies of Knowledge Acquisition from Topographic Map Seires

In recent years, some notable studies of acquisition of knowledge have been conducted. Some studies focus on the acquisition of criteria of geometrical knowledge of individual features or specific procedures and other studies also investigate interrelations among acquired rules. An example of the first type of study is Mark (1991), who clarifies the thresholds for criteria of selection of more than 16 different objects in the attempt of implementation of the identified size thresholds from the study of criteria of selection of each cartographic feature on the instructions for compilation of 1:24,000 scale USGS topographic maps. Although Mark obtains the quantitative thresholds from the USGS rules, he admits the uncertainty of the determination of the optimum of the identified thresholds for their phenomena. His findings leads to such questions, "Even if the rules are most appropriate for USGS 1:24,000 scale products, do the map-scale versions of the thresholds apply effectively to other USGS map scale series? Or to topographic maps for other countries? " (Mark, 1991, pp.116-117).

Buttenfield et al. (1991) studies the 'cartographic behavior' of objects on German topographic map series at four scales ranging from 1:25,000 down to 1:200,000. As Muller (1990, 1991) identifies such abrupt changes in cartographic symbols as 'catastrophic change', which occurs at the point of scale where cartographic features generalized not only geometrically but also conceptually, Buttenfield et al. (1991) suggest that the search to identify scales at which metamorphosis occurs on topographic maps should provide guidelines for formalizing decisions for automate scale-changing In addition, it is acknowledged that collection of such cartographic knowledge may be studied to determine how much the production specifications vary between national mapping agencies, and the extent to which rules cited in production specifications are actually implemented.

As a part of the research, Muller and Mouwes (1990) conduct a study of comparison of national standards of generalization, Netherlands and Great Britain, through the comparison of 1:25,000 maps and 1:50,000 maps of the same area in England with each country's generalization rules. With the interview of the cartographer from the Dutch national mapping agency, who provides the expert knowledge, Muller and Mouwes identify some different treatment of generalization procedures in the maps produced with the Dutch rules and the British rules respectively. However, the comparison is primary based on the visual examination of the produced maps by each country's official generalization rules without any quantitative measurement, comparison of official written generalization rules from Netherlands and Great Britain, or examination of whether each country's rules are actually implemented on the produced maps.

Previous studies suggest the possible research topic, which examines national standards of map generalization criteria to derive intermediate scale topographic maps from larger scale topographic maps from official generalization guidelines or existing topographic maps from multiple countries.

3. Rules from Guidelines

The procedures of generalization which are considered in this study are: selection, classification, simplification, displacement, exaggeration, collapse, typification and refinement. Features are classified as physical or cultural, factual or imaginary (physically invisible on the earth) in terms of their nature. Then, according to their representation on a map, they are further classified as point, line, or area symbols. Thus, each feature is classified into one of twelve categories. These classifications are important as well as useful for analyzing the rules of generalization procedures including the hierarchical orders in the displacement process (Japan Geographical Survey Institute, 1981).

3.1 Methodology

The comparable maps chosen for this study are the 1:50,000 series of topographic maps produced in Japan and the US They are considered comparable because they are both derived from larger-scale products (1:25,000 and 1:24,000) and should demonstrate the applications of rules of generalization. For Japan, *Technical Instructions for Derivation and Revision of 1:50,000 scale Topographic Maps* (1981) was translated into English language and generalization rules were derived. Next, comparable written specifications for US maps were derived by inference from the available documents such as *Accuracy Specifications for Topographic Mapping (1980a), Standards for 1:50,000 and 1:100,000 Scale County Maps* (1984b), and *Features Shown on Topographic Maps* (1980b) by the USGS. It is noted that the extraction of the rules is one-way search, Japanese rules - US rules, but not US rules - Japanese rules. The availability of comparable written specifications for US maps to Japanese rules (for physical features or cultural features) was determined. Next the similarity of each resulting set of rules from each country are evaluated. Out of 101 pages of *Technical Instructions on Derivation and Revision of 1:50,000 Scale Topographic Maps* (Japan Geographical Survey Institute, 1981), 18 pages consist of general principles of generalization as well as 30 rules for how to derive 1:50,000 maps maintaining required accuracy. The rules were classified into a feature type and generalization procedure (see

Table1). Interviews with persons who work on the generalization processes of topographic maps are considered as supportive data for this study. The United States Geological Survey, the Japan Geographical Survey Institute and several sub-contractors in Japan have been interviewed.

3.2 A Comparison of the Rules from Japan and the USA

Table 1 shows the examples of extracted Japanese rules and the comparable US rules. The rules had a

1) Common condition in a IF statement or
2) Common generalization execution in a THEN statement or
3) Common generalization execution between two countries' rules, where the condition for the execution is different.

In this case, the IF statements of each pair of rules will be compared.

In addition, due to the difficulty in finding identical conditions or generalization executions in the US rules to those of Japanese, the criteria has been extended as follows:

4) The rules about similar features to those of the Japanese.

The rules were compared in qualitative and quantitative ways.

Qualitative: hierarchical order among features or their categories; different treatment of the same feature depending upon its condition (e.g., a landmark vegetation should be retained even though it is less than minimum symbol size).

Quantitative: maximum tolerance of accumulative displacements is 1.2 mm on a 1:50,000 scale maps (Rule 23).

Table 1. Example of comparison of rules

	Japanese rules	Equivalent rules in USGS
Rule 20	IF vegetation area is smaller than the minimum size BUT should be shown due to its importance, THEN, the area should be exaggerated to the minimum size.	IF there are narrow strips on woodland and isolated tracts covering areas smaller than the specified minimum, THEN, they should be shown only where they are considered to be landmarks.
Feature	Vegetation area	Woodland area
Feature type	Vegetation area: factual and area	Woodland area: factual and area
Generalization operator	Exaggeration	Selection for exaggeration
Key words	Minimum size, importance	Landmarks
Rule 26	IF there is a conflict in showing of a factual line and an imaginary line, e.g., roads and contour lines, THEN, an imaginary line should be displaced.	Special treatment of contours along roads and railroads is needed to show the route grades as accurately as possible. For mountain roads particularly, the adjacent topography must be displaced to some extent.
Feature	Roads and contour lines	Roads, railroads and lines
Feature type	Roads: cultural, factual, and lines Contour lines: physical, factual and lines	Roads: cultural, factual and lines Railroads: cultural, factual and lines Contour lines: physical, imaginary and lines
Generalization operator	Displacement	Displacement
Key words	Factual line and imaginary line	accurately

4. Discussion

4.1 Treatments of Physical Features

The 15 cross-cultural generalization rules described from parallel rules (C1-C9) as well as non-parallel rules (I1-I6) are identified (see Table 2 and 3). Nine rules among 15 rules are about cultural features, two rules are about physical features, and the remaining four rules are about both physical and cultural features. The only two rules about physical features are about exaggeration and displacement processes of relief features. There are few cross-cultural rules about physical features, both because Japan has only 8 rules out of 30 and because the US has no written generalization rules about simplification and exaggeration processes of hydrographic features while there are four rules in the Japanese guidelines.

Table 2. Cross-cultural generalization rules from written generalization guidelines from Japan and the United States

Rule	Feature	Generalization operator
C-1 IF there is distinctive characteristics of relief feature BUT become illegible on a target map THEN represent them by exaggeration	Relief feature	Exaggeration
C-2 IF contour lines are running together AND become illegible THEN displace them depending upon the circumstance	Relief feature	Displacement
C-3 IF there is a group of buildings THEN the general condition of buildings should be maintained	Buildings	Typification
C-4 IF there are small unevenness of buildings THEN they should be simplified on a target map	Buildings	Simplification
C-5 IF there are rows of detached buildings THEN they should be aggregated AND should be symbolized by the actual number of buildings where space permits ELSE some buildings must be omitted.	Buildings	Aggregation
C-6 IF displacement is necessary among neighboring features of boundary lines THEN relative accuracy among features should be maintained	Boundary lines	Displacement
C-7 IF displacement is necessary THEN relative accuracy among features should be always maintained	All features	Displacement
C-8 In congested area only the representative pattern of roads are maintained	Roads in congested area	Typification
C-9 IF vegetation area < minimum size AND important OR landmarks THEN exaggerate to minimum size	Vegetation area	Exaggeration

The reply from the USGS (Weber, 1993) has suggested the guidelines of simplification processes of contour lines be used for hydrographic features. However, the treatment of relief features and hydrographic features is considered as slightly different in the Japanese rules. Since Japan gives a high priority to hydrographic features during displacement process, the simplification of hydrographic lines is not encouraged, though contour lines are (Ohmori, 1991).

It can be said that relatively few written generalization rules about physical features in both countries reflect the practice of cartographic license, which national mapping agencies rely on experienced cartographers in determining generalization procedures about physical features in both countries.

Table 3. The inferred cross-cultural generalization rules from non-parallel rules

The inferred rules	Feature	Generalization Operator
I-1 IF linear features meanders by fixed features such as a building or a straight road THEN displace the linear features	Linear features and fixed features	Displacement
I-2 IF the area > minimum size THEN show the symbol	Vegetation area	Selection
I-3 Horizontal control points should not be displaced	Horizontal control points	Displacement
I-4 IF there is a conflict between a factual line and an imaginary line THEN displace an imaginary line	A factual line and an imaginary line	Displacement
I-5 IF there is a conflict among three cultural factual features with same importance THEN place the middle feature in true position AND displace other two features equally	Cultural factual features	Displacement
I-6 IF there is a conflict among multiple parallel linear features THEN place the centerline of the most prominent or "controlling" feature in correct position	Linear feature	Displacement

4.2 Treatments of Cultural Features

In the rules of both countries, high accuracy is required at representation of horizontal control points. This is reasonable considering the purpose of topographic maps and the scale of the maps studied in this research. In addition, the characteristics of topographic maps reflect the emphasis on the relative accuracy among features, especially among boundary lines in both countries.

Buildings. There are three cross-cultural rules about buildings. Rule C4 is about the simplification process of an individual building; Rule C5 is about aggregation process of rows of detached buildings; and Rule C3 is about typification process of a group of buildings. It is interesting to have found similarities in various generalization processes and conditions of buildings.

Roads. Furthermore, the typification processes are also emphasized to show representative pattern of roads in congested areas (Rule C8). While different treatment of buildings found in Rule 14 is due to the difference in classification and symbolization of schools, a different emphasis of rules causes the different treatment of plotting trails (Rule 10). While the Japanese rule emphasizes and maintains graphic legibility and makes trails simplified, the US rule emphasizes accuracy and insists trails be plotted in approximate position if necessary.

Vegetation. Rule I1 is the minimum size rule for selection of vegetation area. Although only the selection of vegetation area is mentioned in the Japanese generalization guidelines, the minimum size rule is fundamental to specification of all features. Consequently, a variation of the minimum size rule is seen in the Rule C9, which has importance or landmark factors for exaggeration of symbols which is smaller than minimum size. This result can encourage the future research to study the minimum size of symbols of both source scale maps as well as target scale maps of Japan and the US.

The examination of written generalization rules has revealed notable similarities in treatment of cultural features in Japan and the US. The different treatments discovered are mainly due to the different symbolization and classification, suggesting that the study of symbolization is very important and necessary for future research.

4.3 Hierarchical Orders of Features

Although there are 11 rules in Japanese generalization guidelines and eight cross-cultural rules about displacement processes, the rules do not tell the complete hierarchical orders of features in either country. However, the Japanese guidelines, which take the feature type such as physical/cultural and factual/imaginary into account in the decision-making process, have more detailed orders of features than those of the US. Yet, considering the compilation processes of topographic maps by the cartographers of the USGS and the interviews of the cartographers of both countries, the order of features are identified: control points, hydrography, railroads, roads, cultural water features, other straight line features, buildings, contour lines and other symbols. This fact again suggests that there is the practice of cartographic licenses in how to displace features in both countries and more importantly, the identified hierarchical order of features are cross-cultural in practice in production of 1:50,000 topographic maps, although it is implicit rule.

4.4 Subjectivity in Application of Rules

It is noted that among 15 cross-cultural rules, 13 rules require the cartographers' subjective judgment at the generalization processes. Key words of the rules such as 'distinctive feature,' 'representative patterns of buildings,' 'relative accuracy,' 'important' and 'prominent feature' are the examples which need to be interpreted and executed by the cartographers subjectively. Furthermore, the key words such as 'illegible,' 'small', when related to graphic legibility of maps, are also, to some extent, left to subjective judgments by the cartographers. This fact suggests that both national mapping agencies rely on their cartographer's judgment in deriving topographic maps.

5. Conclusion

The result of this study suggests an important and inherent problem of map generalization, difficulty of formalization of criteria and procedures of generalization. Fuzziness of the rules, which is still subject to interpretation, is incompatible with the requirements for specific execution as identified in the rules studied. Furthermore, it also suggests the limitation the use of manual map generalization rules as source of cartographic knowledge for establishing automated generalization systems. For example, importance of privileged points such as intersection of line features, which is very important concept for typification process in digital cartography, is not found in the written guidelines studied in this study, although the identified cross-cultural rules emphasize importance of maintaining the representative pattern of features. It indicates that what intuitively look obvious to cartographers are not always in manual generalization guidelines. A lack of solution in how to maintain relative accuracy among features in the studied written rules is another problem, i.e., establishing topology, which is a required structure for comprehensive automated generalization.

This study has focused to identify common map generalization criteria in Japan and the United States and has identified some similarities and differences. Still, cartographic knowledge examined here is the 'how' aspect of generalization. Further investigation of 'deep' cartographic knowledge, i.e., the 'why' aspect of the identified similarities and differences in Japan and the United States would be challenging but important future research in order to develop more comprehensive rule-base for map generalization.

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