

ANIMATING BASIC OPERATIONS FOR DIGITAL MAP GENERALIZATION WITH MORPHING TECHNIQUES

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ABSTRACT:

This paper describes an animation for multi-scale representation of spatial data. More specifically, morphing technique is employed to animate the operations for the geometric transformations in digital map generalization. Operations required for the geometric transformations are first introduced; morphing technique is then described; the animation of these operations with morphing technique is presented at last.

1. INTRODUCTION

The multi-scale issue related to map production is the derivation of maps at a smaller scale from those at a larger scale, which is a process traditionally termed as a *generalization*. Although map generalization is a traditional topic, yet the generalization of maps in digital environment, simply digital map generalization, is a result of computerization in recent decades. Although it is difficult to locate the exact date on which research on digital map generalization started, yet one saw three very important publications appeared in 1966, i.e. Tobler (1966), Töpfer and Pillewizer (1966) and Perkal (1966). It has been over 40 years already since the publication of these first three important papers. An age of 40 has special meaning in Chinese – *enlightenment*. It means that one will rarely be puzzled after this age (Li, 2007a). Accordingly, a discipline after 40-year development should have been well established. Indeed, this maturity is signified by the formation of its mathematical/algorithmic foundation recently, which is presented systematically in the book “*Algorithmic Foundation of Multi-scale Spatial Representation*” (Li, 2007b). In that book, six sets of geometric operations with a total of 40 were differentiated for the generalization of individual points, point cluster, individual lines, line sets, individual areas and area sets. At least one algorithm is made available for each of these operations.

Regarding the operations of geometric transformations, an important task is to make people understand the transformations clearly. This seems to be not an easy task. A study carried out by Rieger and Coulson in early 1990s (1993) revealed that some of the operations were even not understood at all, although there were only 12 or so operations at that time. Therefore, attempt is made here to use morphing technique to animate the 40 generalization operations differentiated by Li (1997b) to make them more intuitive.

2. SIX SETS OF OPERATIONS FOR DIGITAL MAP GENERALIZATION

In classic textbook, only very few operations are identified, e.g. “classification, induction, simplification and symbolization” by Robinson et al (1984) and “aggregation, combination,

simplification, displacement and selective omission” by Keates (1989). However, these operations are too general to be computerized. That is to say, more concrete operations need to be identified. From the late 1980s, researchers try to identify more concrete operations. For example, Beard and Mackaness (1991) identified 8 operations. McMaster and Shaea (1992) have identified a list of 12 operations. A summary of currently available operations is given in Table 1.

However, these operations are still too general to be computerized. Indeed, by the same term it may mean different things in different situation. Li (2007b) has carried out a systematic study of possible operations and produced six sets of operation with a total of 40, i.e. a set of individual points, a set for point cluster, a set for individual lines, a set for line sets, a set for individual area features and a set for area sets.

The operations for individual point features are shown in Figure 1 and defined as follows:

- Elimination: to eliminate an individual point feature, as it will be too small to represent;
- Magnification: to make the size of a point feature become large enough to be represented, although it appears too small to be represented;
- Displacement: to move a point away from a feature or features because the distance between the point and other feature(s) are too small to be separated.

The operations for a set of point features are shown in Figure 2 and defined as follows:

- Aggregation: to group a number of points into a single point features;
- Regionalization: to outline the boundary of the region covered by points so as to make this region an area feature;
- Selective omission: to select those more important point feature to be retained and to omit less important ones, if space is not enough;
- Simplification: to reduce the complexity of the structure of point cluster by removing some point with the original structure retained;
- Typification: to keep the typical pattern of the point feature while removing some points.

The operations for individual line features are shown in Figure 3 and defined as follows:

- Displacement: to move the line towards a given direction;
- Elimination: to eliminate an individual line feature, as it will be too narrow to represent;
- (Scale-driven) generalization: to produce a new line in which the main structure is retained by small details are removed. This operation is dependent on the scales of input and output representations;
- Partial modification: to modify the shape of a segment within a line;
- Point reduction: to reduce the number of points for representation by removing those less important points from a line so that only those so-called critical points are retained;
- Smoothing: to make the appear to be smoother;
- Typification: to keep the typical pattern of the line bends while removing some.

The operations for a class of line features are shown in Figure 4 and defined as follows:

- Collapse: to make the dimension changed. Two types are identified, i.e. ring-to-point and double-to-single-line.

- Displacement: to move one away from the other or both lines away from each other;
- Enhancement: to make the characteristics still clear;
- Merging: to combine to two or more close lines together;
- Selective Omission: to select those more important ones to be retained.

The operations for individual area features are shown in Figure 5 and defined as follows:

- Collapse: to make the feature represented by a symbol with lower dimension,
- Displacement: to move the area to a slightly different position, normally to solve the conflict problem;
- Elimination: to eliminate those small and unimportant areas;
- Exaggeration: to make a area with small size still represented at a smaller scale maps, on which it should be too small to be represented;
- Simplification: to make the shape simpler;
- Split: to split an area features into two because the connection between them is too narrow.

Operations	Large-scale	Photo-reduced	Small-scale
Displacement			
Elimination			
Magnification			

Figure 1 Operations for geometric transformations of individual point features

Researchers Operations	Robinson et al (1984)	Keates (1989)	Delicia & Black (1987)	McMaster & Monmonior (1989)	Beard & Mackaness (1991)	McMaster & Shea (1992)
Agglomeration			√			
Aggregation			√	√		√
Amalgamation				√		√
Classification	√				√	√
Coarsen					√	
Collapse			√	√	√	√
Combination		√			√	
Displacement		√		√	√	√
Enhancement				√		√
Exaggeration		√			√	√
Induction	√					
Merge				√		√
Omission		√		√	√	
Refinement			√	√		√
Selection		√			√	
Simplification	√	√	√	√		√
Smoothing				√		√
Symbolisation	√					
Typification						√

Table 1 Existing operations for digital map generalization (Modified from Su 1997)

Operations	Large-scale	Photo-reduced	Small-scale
Aggregation			
Regionalization			
Selective Omission			
(Structural) Simplification			
Typification			

Figure 2 Operations for geometric transformations of a set of point features

Operations		Large-scale	Photo-reduced	Small-scale
Displacement				
Elimination				
(Scale-driven) generalisation				
Partial modification				
Point-reduction				
Smoothing	Curve-fitting			
	Filtering			
Typification				

Figure 3 Operations for geometric transformations of individual line features

Operations		Large-scale	Photo-reduced	Small-scale
Selective omission				
Collapse	Ring-to-point			
	Double-to-single			
Enhancement				
Merging				
Displacement				

Figure 4 Operations for geometric transformations of a set of line features

Operations		Large-scale	Photo-reduced	Small-scale
Collapse	Area-to-point			
	Area-to-line			
	Partial			
Displacement				
Exaggeration	Directional thickening			
	Enlargement			
	Widening			
Elimination				
(Shape) Simplification				
Split				

Figure 5 Operations for geometric transformations of individual area features

Operations	Large-scale	Photo-reduced	Small-scale
Aggregation			
Agglomeration			
Amalgamation			
Dissolving			
Merging			
Relocation			
(Structural) Simplification			
Typification			

Figure 6 Operations for geometric transformations of a set of area features

The operations for a class of area features are shown in Figure 6 and defined as follows:

- Agglomeration: to make area features bounded by thin area features into adjacent area features by collapsing the thin area boundaries into lines;
- Aggregation: to combine area features (e.g. buildings) separated by open space;
- Amalgamation: to combine area features (e.g. buildings) separated by another feature (e.g. roads);
- Dissolving: to split a small area into pieces (according to adjacent areas) and to merge these pieces into their corresponding adjacent areas;
- Merging: to combine two adjacent areas into one;
- Relocation: to move more than one features around normally to solve the conflict problem;
- Structural simplification: to retain the structure of area patches by selecting important ones and omitting less important ones;
- Typification: to retain the typical pattern, e.g. a group of area features (e.g. buildings) aligned in rows and columns.

The term *point-reduction* is not widely used. In some literature, it is referred to as line simplification, as some kind of simplification effect might be created. Indeed, it has been argued by many (e.g. Li, 1993) that point reduction shouldn't be regarded as a generalization operation because traditional generalization has nothing to do with point reduction. In fact, point-reduction algorithms try to make best approximation of the original line with a minimum number of points, thus they are also called *curve approximation* algorithms. More appropriately, such an operation should be termed as *weeding*. It must be emphasized here that no scale change is involved in such an operation. The output is still for the representation of the original line at the original scale. The smoothing (including curve-fitting and filtering) also has no direct association with scales. *Scale-driven generalization* is a specific type of smoothing. In scale-driven generalization, the smoothing effect is computed based on the scale of input data and the scale of the output data. In the end of such a process, the main trend of the line is retained and small variations are removed. In practice, point-reduction should also be applied to lines as a preprocessing or post-processing of scale-driven generalization because the points on a line will appear to be too dense after a scale reduction.

3. MORPHING TECHNIQUE FOR ANIMATION

Morphing is a special effect in motion pictures and animations that changes (or morphs) one image ("before" image) into another ("after" image) through a seamless transition. Figure 7 is an example of morphing which changes US President George Bush to Hollywood film star Arnold Schwarzenegger (http://en.wikipedia.org/wiki/Morphing). Traditionally such a depiction would be achieved through cross-fading techniques on film. However, nowadays, this is achieved by computer software. A large number of free morphing software is available and can be downloaded from the Internet (e.g. from http://www.freedomdownloadcenter.com/Search/morphing.html). In this project, the Morpheus Photo Morpher™ v3.1 (http://www.morpheussoftware.net) was used.

Indeed, the mid picture of Figure 7 is a result of equally-weighted interpolation between the left ("before") image and

the right ("after") image. This process is called *cross-dissolve*. To make the interpolation easier, it requires that the size and shape of the two images are identical. If a heavier weight is taken from the left image for the interpolation, then the result will have a higher similarity to the left image, and vice versa. To make the animation look smoother, a series of intermediate images could be produced by *cross-dissolve*.



Figure 7 Example of morphing (http://en.wikipedia.org/wiki/Morphing)

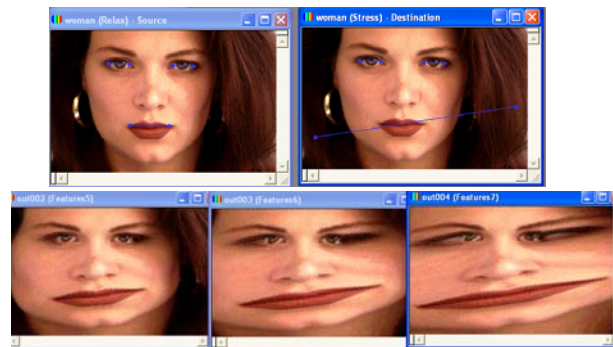


Figure 8 Wrapping and dissolve processes in morphing

To make the two images of equal size and identical shape, they need to be co-registered. This process is called wrapping, which is to distort one image to match the other. To achieve the matching, some corresponding points and vectors on the "before" and "after" images need to be used. Figure 8 shows the distortion of a lady's picture according to a set of given vectors. Intermediate pictures can then be produced through cross-dissolve.

4. ANIMATING GENERALIZATION OPERATIONS WITH MORPHING TECHNIQUE

There, the steps involved in a morphing process are as follows:

- Establishment of control (referencing)
- Wrapping the image
- Cross Dissolve

The control could be points (leading to the term *point morphing*), and/or lines (leading to the term *line morphing*). Figure 9 shows the series of intermediate images produced by the software plus the original two images. The final animation of a film is produced from this series of images, which shows the smoothing process of the boundary. Figure 10 shows another example but for aggregation operation.



Figure 9 A series of images produced for animation by morphing software for shape simplification

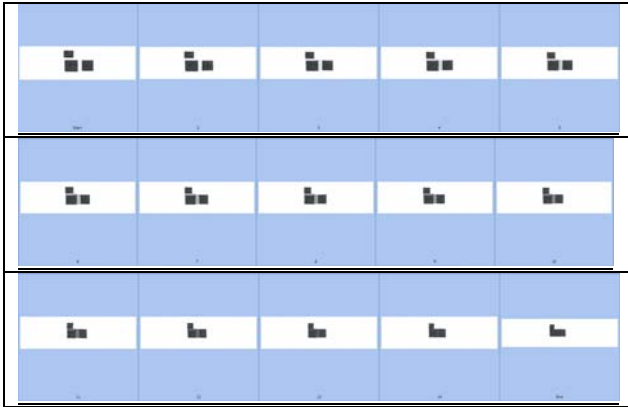


Figure 10 A series of images produced for animation by morphing software for aggregation

5. CONCLUDING REMARKS

This paper presents an idea to make use of the morphing technique to visualize the geometric transformations involved in the generalization. A public domain software has been used. In fact, an evaluation of the animations has been conducted although not presented here due to space limitation. The results reveal that morphing is an effective animation for this purpose!

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