

AN ADAPTIVE LATTICE MODEL AND ITS APPLICATION TO MAP SIMPLIFICATION

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ABSTRACT:

In this paper, we propose an Adaptive Lattice Model (ALM) for simplifying linear features of geographic data. An ALM, based on spatial constraints or the target resolution of the data to be created, represents spatial data by latticing adaptively the spatial space at the target resolution and omitting all details smaller or finer than the resolution. Out of two implementations of ALM, this paper presents the GRID implementation, which moves all vertexes of the features to the nearest point or one of the corners of lattices in ALM. By GRID, all coordinates are rounded up to the integral multiple of the resolution. Since by GRID implement, different vertexes may be translated to the same grid, it can be used to simplify features of spatial data. The simplification operations derived from GRID include connection, division, collapse, elimination, and separation. Experimental simplification results are also presented to show the validity of the present model.

1. INTRODUCTION

Map is an important way of representing geographic data, and is usually measured with a scale, which is defined as “the ratio between the size of an object on the map and its real size on the ground” (Johnston 1999). Changing a map’s scale to a smaller one requires the process of generalization, which transforms the original spatial dataset to a coarser representation of the real world. The purpose of generalization is to preserve as much valid information at the target resolution as possible, while reducing as much the amount of data as possible. In other words, some features or details in the original data may be hidden, aggregated, simplified, or deleted, depending on the target resolution.

There are many researches on the generalization of geographic data (Krevelde 1998; Johnston 1999; Peng 2000; Harrie 2000). And the Douglas-Peucker-Ramer algorithm, proposed independently by Ramer (1972) and Douglas and Peucker (1973) respectively, is suggested to be the most visually effective polyline (linear feature) generalization heuristic.

In this paper, an Adaptive Lattice Model (ALM) based on final resolution (target resolution) or spatial constraints of the data to be created is proposed. An ALM represents geographic data by latticing adaptively the spatial space at a certain abstraction level or spatial resolution and omitting all details smaller or finer than the resolution. There are two types of implements for the omission of details. One is GRID, which moves all vertexes of the objects to the nearest point or one of the corners of lattices in ALM, whose coordinates are the integral multiple of the resolution. Here, the movement of a vertex is also called rounding up. The other one is CELL, where every lattice is considered as a cell whose characteristics are statistically measured as a whole. This paper concentrates on the GRID implement of ALM, leaving the CELL implement to another paper (Wang, 2002).

This paper is organized as follows: chapter 2 gives detailed description of ALM, chapter 3 discusses the GRID implement and its related operations such as connection, division, collapse, elimination, and separation are discussed. Chapter 4 presents the implementation of GRID. Chapter 5 gives experimental results to show the validity of the present model.

2. ADAPTIVE LATTICE MODEL

Since the detailed description of ALM has been presented in another paper (Wang, 2002), this paper only gives its brief summary.

A geographic dataset is a kind of representation of the real world, and the generalization of geographic data is only for generating a variety of representation. Although geographic data may be represented on maps with a range of different scales, the validity of observations or inferences drawn from such maps depends upon the resolution of the representation and the viewer’s resolution. Considering the observation of a geographic dataset as an imaging system with a CCD camera, what the observer sees are pixels arranged in two-dimension, where each pixel corresponds to and represents statistically a region of the geographic data. Figure 1 shows a typical example.

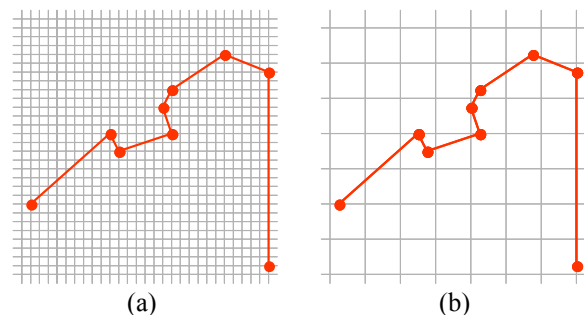


Figure 1. Lattice model of generalization

Figure 1(a) shows the original data latticed with a higher resolution, and figure 1(b) shows the same data with a lower resolution. Every rectangle or cell of both left and right images works in the same principal as a CCD cell. That is to say, we cannot identify the details within a cell. In other words, an observer can only take a rectangle as the total representation of the corresponding region. The total representation may be whether there are any vertexes in the region, or whether there are any segments crossing with the region, etc.

An Adaptive Lattice Model (ALM) is defined as follows: when geographic data is confined to a predefined lattice where every edge's length is equal to the target resolution, a generalized result of the geographic data will be obtained by calculating the total representation of the corresponding region of the data for every cell. For example, we can check if there are any vertexes of polylines in a rectangle, or calculate the overlapping area's percentage between a rectangle and a polygon in the geographic data. Different calculating methods may be used to generalize various geographic data. In our research, there are two kinds of methods for estimating the features in every cell. One is a statistic method by which the feature is estimated statistically for every rectangle. Another is a direct method where all vertexes' coordinates are rounded up to the integral multiple of the target resolution. The former method, which is based on the statistic characteristics of every cell and called CELL implement of ALM, is useful for generalizing face features or polygon data. The later one, called GRID implement of ALM because it is equal to moving all vertexes to the nearest GRID, is suitable for simplifying linear features or polyline data. The following chapters will concentrate on the GRID implement and its application to the simplification of geographic data.

3. GRID AND ITS OPERATIONS

As stated above, GRID is an implementation of ALM by moving all vertexes of the objects to the nearest point or one of the corners of lattices in ALM. As to the translation of vertexes are within the nearest rectangle of each vertex, the statistics of the region data in every cell will not be changed. With GRID, the generalization process is simplified to rounding up all vertexes' coordinates to the integral times of the target resolution and analysing the relationship among all rounded vertexes. For example, a pair of adjoining vertexes will be merged if their rounded coordinates are equal to each other; a polyline may be split if a middle vertex of the polyline is going to be merged with a point of another polyline after the latticing procedure; etc. The following sections will show some typical operations based on GRID for simplifying geographic data.

3.1 Collapse

GRID based Collapse merges features of the same type if their vertexes are rounded up to the same grids in ALM. Figure 2 shows some examples of collapse with GRID, marked as *A* (see the next section for *B*). Figure 2(a) shows a pair of road edges and some river polylines. Figure 2(b) shows the collapsed results with the decrease in resolution. As shown in figure 2(b), the pair of the road edges are shifted to the same grids and collapsed to one polyline. Similar result is also obtained for the polylines of the river.

3.2 Elimination

Elimination includes deleting duplicated vertexes when adjoining vertexes are rounded up to the same grid and abandoning the middle points when its neighbouring points are colinear. Some examples of elimination are marked as *B* in Figure 2.

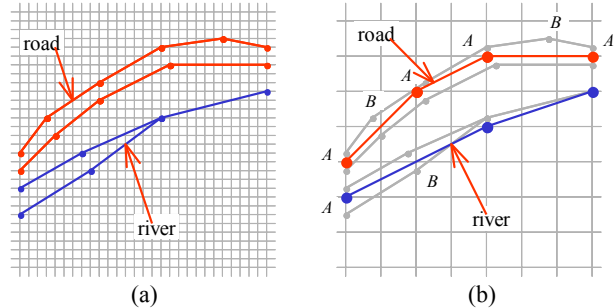


Figure 2. Collapse/elimination with GRID

3.3 Connection / Aggregation

Connection merges two or more different features in the case when one or more of their vertexes are transformed to the same grids during latticing. The upper half of figure 3 shows an example of connection (marked as *A* in the right graph) between two buildings *a* and *b*, when they are simplified by using GRID implement of ALM. Here, the adjoining edges of buildings *a* and *b* become partially overlapping after latticing. After deleting the overlapping part, the reserved edges are connected to create a large building. The connection of face features is also called aggregation in the generalization of geographic data.

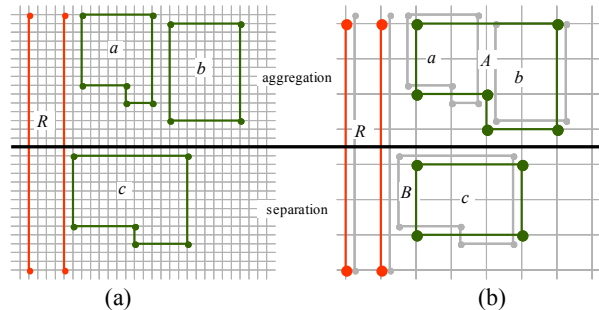


Figure 3. Connection/separation with GRID

3.4 Separation / Displacement

Separation or displacement appears when points consisting different types of features are latticed to the same grid. Since they belong to different coverage, they cannot be merged or connected to create a new feature, like the connection of two buildings mentioned above. In such case, the feature with less importance must be displaced with a certain distance away from the more important feature. The lower half of figure 3 shows another example, where one edge of building *c* overlaps with road *R* when they are latticed, and the overlapped edge of building *c* has been shifted to separate it from road *R*.

3.5 Division

Division occurs in the case of intersection between two different features. Consider a river, which is represented by a pair of polylines, and its width varies. When the river is simplified by using a given resolution, the narrower parts of the river may be

collapsed to a single polyline with width 0, but the left should be still represented with two polylines. Then, the collapsed parts and the left parts must be divided first. Figure 4 shows one example of the division based on GRID.

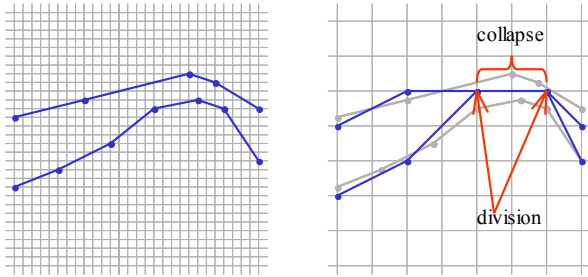


Figure 4. Division with GRID

4. SIMPLIFICATION WITH GRID

We propose a new simplification model based on GRID, including collapse, elimination, connection, division, and their combination. The processing flow is shown in Figure 5.

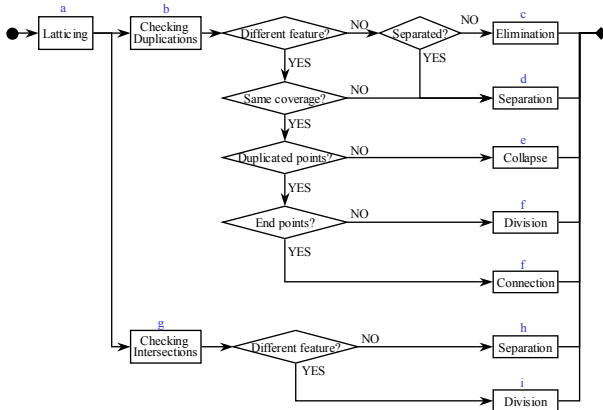


Figure 5. Processing Diagram

The present simplification mode includes the following steps:

- a) Latticing all vertexes of features with the following equation.

$$x_r = r \cdot \text{round} \left(\frac{x}{r} + 0.5 \right) \quad (1)$$

$$y_r = r \cdot \text{round} \left(\frac{y}{r} + 0.5 \right)$$

where, r = target resolution

x, y = coordinates before latticing

x_r, y_r = coordinates after latticing

$\text{round}(z)$: return the largest integer which is less than or equal to z .

- b) Checking duplicated vertexes and segments.
Duplicated vertexes are those points which are originally different but locates at the same grid after being latticed. If a segment of one feature overlaps partly or entirely with a segment of another feature after being latticed, the overlapping segments are called duplicated segments.
- c) Eliminating duplicated vertexes and segments.
If the duplicated vertexes and segments are from the same feature and adjoining with each other, the duplicated one

should be deleted to keep the uniqueness of the simplified data.

- d) Separating overlapped segments and duplicated vertexes.
There are two cases for separation for duplications. One case is the separation of overlapping segments and duplicated vertexes, if they belong to the same feature but do not adjoin each other. The other case is the separation of duplications that belong to different coverage.
- e) Collapsing overlapped segments.
If the overlapped segments are the parts of same road edges or the same riverbanks, the overlapping segments will be merged to one segment, and the original features, road edges or riverbanks, are collapsed from areas or pairs of polylines to single polylines.
- f) Dividing features at the duplicated vertexes.
If one of the duplicated vertexes is not the end-point of the original feature, the original feature should be divided into two features to convert the duplicated vertexes to nodes. Otherwise, the two features should be connected with each other to create a new large feature.
- g) Checking intersections.
Latticing vertexes of all features may cause intersections between segments. Checking of intersections is for identifying such intersections.
- h) Separating the intersections of the same feature.
An intersection between two different segments of the same feature indicates a loop error. To avoid loop generation, the intersection should be settled by separating them with each other or deleting the loop if the area of the loop is small enough.
- i) Dividing crossing features.
If the intersection happened between two different features, one or both features may be divided to make the cross point be a new node, which is the end point of each divided feature.

5. EXPERIMENTS

Based GRID implement and its operations, we constructed a prototype system for simplification of geographic data. Figure 6 shows the main window of the prototype system.

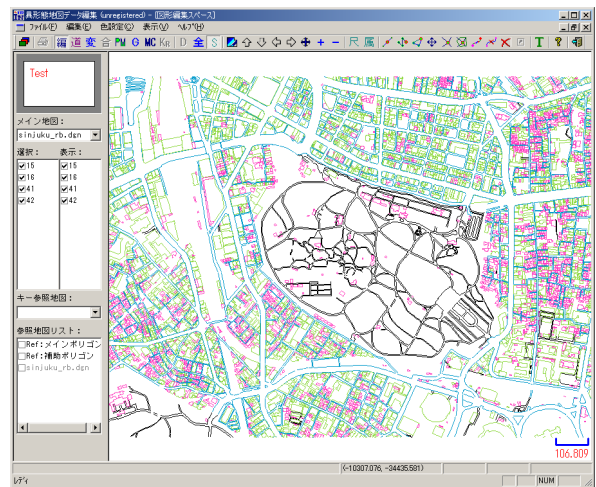


Figure 6. Main window of the prototype system

We applied the prototype system to some sample data of real world and have obtained some promising results. The upper image in figure 7 is the original data, in which filled areas

represent roads. The lower image is the simplified result, where narrow roads are collapsed to single polylines and the wide roads still remain as areas.



Figure 7. Simplified result. Upper image: original roads (1/2500), lower image: simplified results (1/25000)

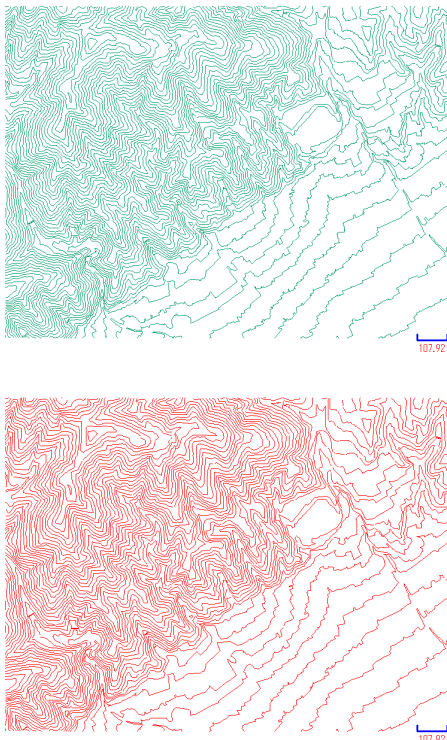


Figure 8. Simplified result. Upper image: original contour lines (1/2500: 44304 points / 1370 objects), lower image: simplified contour lines (1/10000: 21474 points / 1315 objects)

Figure 8 shows a result of simplified contour lines. Here, the upper image is the input data with 1370 contour lines consisting of 44304 points. After simplification with the proposed ALM model, the result, shown as the lower image, becomes 1311 contour lines consisting of 21474 points.

6. CONCLUSION

This paper has presented an Adaptive Lattice Model, especially its GRID implement, for simplification of geographic data. Simplification operation includes elimination, separation, collapse, connection, and division, etc. The present model has also been demonstrated to be simple and effective through some experiments.

As future works, we are going to improve our model to preserve the non-intersection property of the simplified linear features. We are also going to further integrate the two implements, GRID and CELL, to implement other operations which are necessary for generalizing geographic data.

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