RAPID ALGORITHM OF BUILDING TYPIFICATION IN WEB MAPPING

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ABSTRACT:

When comes to on-demand or real-time web mapping, difficulties is how to support adaptive and intelligent zooming and to generate web map that meeting user request rapidly. Solutions can be categorized into three approaches. However they do not fulfil the requirements for reason of performance or economy. The new strategy which intends to integrate multi-scale databases and on-the-fly generalization is admired. The key point here is how to choose map scales in a multi-scale database and to develop effective online generalization operators to achieve balance between performance and economy. This paper mainly concerns building typification in the context of web mapping application. After pointing out the advantages of mesh simplification technique adapted by (Alessandro, 2003), further research shows that it is not a good delegate for the idea of integration. Thus an algorithm to typify buildings based on data matching is proposed by spatial partition and clustering. The matching process is composed of three stages, i.e. many-to-many matching by means of spatial partitioning, many-to-one matching by means of spatial clustering method, data enhancement and storage in specified data structure of building object. The typification procedure of buildings contains three steps. The first step is to determine the number of buildings on user request map using improved radical law. The second step is to determine the representation of new buildings in each cluster iteratively by reduce one building each time. The third step is to harmonize the size of buildings considering the minimal separate distance of building itself and the preservation of differences between buildings. Advantages and disadvantages of this method are detailed. At the end of this paper the conclusions，possible improvements and authors' next research focuses are proposed.

1. INTRODUCTION

How to generate web map that meeting user request rapidly is a very popular research issue in the field of web mapping. There are many related projects globally such as GiMoDig (Geospatial Info-mobility Service by real-time Data-integration and generalization) funded by European Union, MurMur (Multi Representations-Multi resolutions), WipkA (Wissensbasierter photogrammetrisch –kartographischer Arbeitsplatz) in German, GENDEM (Map Generalization for Thematic and On-Demand Mapping in GIS) in Swiss, Gemure (Generalization and Multiple Representations for On-Demand Map Production and Delivery) in Canada etc. al. This paper absorbs some idea of (Alessandro, 2003) who want to integrate multi-scale databases and on-the-fly generalization and investigates how to choose map scales. Different from (Alessandro, 2003) in which mesh simplification technique is used to typify buildings, this paper proposes an algorithm to typify buildings based on data matching by means of spatial partition and clustering. The algorithm embodies the idea of 'divide and conquer' and integration of multi-scale database and on-the-fly generalization. The building typification procedure contains three steps to determine the number, position and representation of new buildings. The algorithm proved to be rapid and effective in web mapping.

2. PROMISING STRATEGY

When comes to on-demand or real-time web mapping, difficulties is how to support adaptive and intelligent zooming (Hongsheng Li and Cheng Li, 2004). It origins from the well-known bottleneck of cartography and GIS, i.e. automatic cartographic generalization. Solutions can be categorized into three approaches: the representation-oriented approach, the derivation-oriented approach and the process-oriented approach. The representation-oriented approach is technically easiest and most widely used in web environment. It stores several scale-fixed databases (MSDB) thus is not flexible to user request. Meanwhile the propagation update process between different LOD is very difficult and the cost of construction, store and maintenance is considerable. At the user's view there exists obvious transition when they zoom from one scale to another scale. In contrast, process-oriented approach is technically demanding and scarcely used in the context of web mapping. It relies on single and complete data set and can generate map with arbitrary scale and theme such that it is flexible and adaptive to interactive web application. However cartographic generalization is complex and then results long response time of a user request. The derivation-oriented approach is a further development of the idea of the representation-oriented approach, but the scale levels are not independently generated but derived from one detailed base data set applying a semi-automatic generalization process such that data in different levels is consistent.

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Advantages and disadvantages of above approaches are detailed in (Alessandro, 2003). As they do not fulfill all the requirements for use in web mapping, a new strategy is developed by (Alessandro, 2003). The idea is to integrate multi-scale databases and on-the-fly generalization. It contains two phases. The first phase is the construction of a multi-scale database offline. The second is online generalization triggered by a user request. This strategy seems significant and realistic nowadays and keeps the overall process more flexible and reasonable. It will promote real-time and especially on-demand web mapping greatly. The key point here is how to choose map scales in a multi-scale database and to develop effective online generalization operators to achieve balance between performance and economy.

3. HOW TO CHOOSE MAP SCALES IN MULTI-SCALE DATABASE

When applying the new strategy the first and most important issue is to choose adaptive map scales. The guideline is given as follows:

1. The scale span should neither be too large or else it will be not convenient for online processing nor be too small or else it will bring more redundancy to database and expenses will be considerable.
2. Different generalization operators react on different map scale spans according to the concept 'Generalization Point' by (Ratajski, L., 1967). When the map scale is reduced to a certain degree the map load would be limited, thus a new cartographic method should be used and another generalization cycle begins.
3. Different features of different scales appear different in topographic map. Given buildings as an example. Most objects are rendered as identical but reduced polygons with counterparts in real world. As map scale becomes smaller representation of buildings will be changed into rectangle, oriented-point, build-up area, and settlements according to magnitude or even units of area (Glover, E., Mackaness, W., 1999 and Robert, B.M., 1991).
4. National base map series of topographic map and available data sets are also important factors.

This paper mainly concerns building typification in the context of web mapping application. Typification is usually defined as 'reduction of building numbers while preserving the appropriate characteristics'. It is a kind of context generalization. At this point the main information that needs to be kept no longer relate to single houses but to patterns and local characteristics of building groups (Regnauld, N., 2001). The method discussed here collapse each building as its gravity center, transform area clusters into point clusters and meantime recognize buildings as rectangles. The generalization point relates not only to scale but to landscape of cartographic area. In China buildings in urban area and rural area are represented differently. Buildings in dense area and sparse area should be distinguished. This paper restricts its research to building typification operator in urban area in China. The map scales range from 1:25'000 to 1:200'000.

4. MESH SIMPLIFICATION TECHNIQUE APPLIED IN BUILDING TYPIFICATION

4.1 It fall short of the strategy

A new method is introduced by (Alessandro, 2003) to typify buildings. The total procedure is composed of two steps i.e. position and representation. Position determines the number and position at medium LOD (Level of Detail) using iterative edge collapse in mesh simplification technique. Representation is to compute the size and orientation of new buildings (Alessandro, 2003). The method is a kind of simple, decisive and novel approach to cartographic generalization.

Mesh simplification technique origins from computer graphics. It mainly concerns about approximate triangle meshes of three dimensional object surfaces and aims to minimize the error (mathematically or visionally) between simplified model and original one. Progressive meshes by Hoppe can generate continuous LOD model and support multi-resolution display, progressive transmission, mesh compression and selective refinement. The basic idea is to view mesh simplification as a kind of optimization problem which searching vertexes and its connectivity that minimize the energy function (Hoppe H., 1996). However the final aim of operator 'typification' is to preserve characteristics while reducing the quantity. Furthermore most of methods that are applied in high dimensional space can be adapted to low dimensional space from the point of methodology. The gravity center of each building can be adopted as sample point of meshes. Definitely it is feasible to use mesh simplification technique to typify buildings. (Alessandro, 2003) adapted Hoppe's energy function, introduced distance attribute and simplified meshes by iterative edge collapse.

However the mesh simplification technique is not a good delegate for the idea of integration MSDB and cartographic generalization. Reasons are given as follows:

1. The idea that integrates the MSDB and online generalization indicates that there exist more than 2 meshes at least. Suppose M1 is original meshes and M2 is simplified meshes. Now users want medium state. According to this idea it is natural to suppose that M2 should restrict or accelerate the simplification process of M1 in quantity or even in quality to make sure all the implicit and explicit information contained in both model to be utilized. However many mesh simplification techniques only simplifies M1 to a certain degree and can not bring M2 into consideration.
2. Generally speaking, it is difficult to get meshes which are consistent in shape and topology with original meshes. M2 is not necessarily attained by simplification algorithm from M1 and different algorithms also provide different results. In the context of building typification it results differences between simplified building data and original one which are in the same scale. Details can be found in (Alessandro, 2003).

4.2 Possible improvements

Two approaches can be taken into account to utilize the idea of integrating MSDB and on-the-fly generalization sufficiently so as to accelerate building typification:

1. If simplified meshes M2 are attained from original meshes M1, records of simplification process can be used to speed up generalization and zooming in and out between different LOD progressively i.e. adaptive zooming will be supported.
2. Otherwise implicit or explicit linking relations between different LOD need to be constructed.

Both approaches can make the simplification of M1 to be referred by M2 in quantity or even in quality in order to ease the complex procedure. However the first one can not find its application soil for spatial data sets series constructed by mesh simplification technique is not available nowadays. So the second method which links LOD explicitly is adopted in this paper.

5. BUILDING TYPIFICATION BASED ON MULTI-SCALE DATA MATCHING

Questions can be formalized as follows. There exists two topographic maps of the same region but are in different map scales. One is LOD_S (with scale M_S) and another is LOD_B (with scale M_B). Suppose both of them are good enough as original data, how to get medium LODx (with scale M_X) that can mostly preserve building characteristics. As can been seen the simplest way is directly to zoom in and out. It can be applied when M_X is beside M_B and M_S. So application limit of every LOD need to be set inside which simple zooming works and outside which operator typification come into play (Alessandro, 2003). Only typification process is discussed here for its complexity.

5.1 Organization of spatial data

5.1.1 Spatial partitioning and many-to-many matching

The data matching process consists of the computation of correspondence relations between sets of geographical entities which represent the same phenomenon of the real world as two different representations (Alessandro, 2003). Data matching brings back many benefits. On the one hand it can depict linking information of different representations such that data sets of diverse sources, map scales, and themes can be integrated into single data set of MSDB. On the other hand it contains information that can deduct new representations from available one so as to simplify and accelerate the subsequent generalization process. For the realization of the matching process four main approaches must be distinguished: Matching based on semantic criteria; Matching based on geometric criteria; Matching based on topological criteria; Combination of two or all of the above (Alessandro, 2003). Matching based on geometric criteria is to detect corresponding objects by geometry feature, i.e. position, shape etc. Difficulties lie in detection of corresponding object (object group) with same representation for their shape is apt to change and even collapse. Possible match results can be [1:1], [1: n] or [n: m] $\forall n, m \neq 1$.

Obviously relation [1:1] is scarce when matching spatial data sets of different scale. The counterparts of one object in LOD_S usually will be several objects in LOD_B, especially for buildings. The relations between them are [n: 1] or [m: 0] $\forall n, m \neq 1$. Then spatial partitioning method (Regnauld, N., 2001, Alessandro, C., 2003 and Oosterom van P., 1995) is applied to matching building groups, i.e. to build many-to-many relations. Rivers and roads structure the space and both can be used to partition map space. Road network is selected here. Detailed methods are borrowed from (Alessandro, 2003). As result each building is assigned a Group_ID.

5.1.2 Spatial clustering and one-to-many matching

After many-to-many mapping buildings of every group are further matched into one-to-many relations. One approach here is spatial clustering in every group. Suppose number of clusters is the building number in LOD_S. Objects to be clustered are buildings in LOD_B. Method applied here is spatial clustering method based on Euclid distance. After this [1: m] correspondence between the buildings in LOD_S and LOD_B is acquired by further matching based on position. There are many matching methods in this context. The first and easier one is to compute the cluster center of each cluster in LOD_B and compare with the building gravity coordinates in LOD_S; the other approach is to construct the convex hull for each cluster in LOD_B and then to detect buildings in LOD_S will fall into which convex area. Both method works very well. Linking relations are built between objects 1~6 in LOD_B and object 10 in LOD_S in Figure 1.

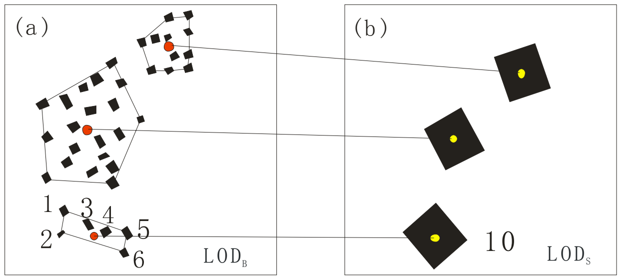

Figure 1 Data matching of buildings in different LOD

Matching results can be recognized as many clusters (many-to-one). There are three clusters in Figure 1. According the idea 'divide and conquer' if computation can be processed in every cluster it will be more effective and rapid. Also this approach integrates multi-scale data bases and online processing and embeds the idea of accelerating simplification of objects in LOD_B by corresponding objects in LOD_S. One point to be aware is that evaluation of spatial clustering should be done to detect and correct cases that are improperly matched.

5.1.3 Data enrichment and data structure of building object

Data enrichment can be defined as follows: Adding different kinds of information to an existing base data set to make it more valuable for a properly defined application (Alessandro, 2003). It aims to simplify the on-the-fly generalization procedure here. Boundaries of area objects and point objects are not very clear in topographic map. When map scale is reduced area object can be represented as point object. In map data processing and specifically typification of buildings or lakes area objects often collapse to points. This kind of dimension reduction can simplify complex problems. However it also introduces information loss and the application scope such as map scale range and landscape of cartographic area need to be defined. Another advantage of data enrichment is to make up with the information loss.

Data structure of building object is redesigned for generalization operator 'typification'. See Table 1. ID_LOD_S or ID_LOD_B is identity code of building in correspondent LOD; X, Y are coordinates of gravity of each building; Area is area of building; Orientation is defined as angle between the longest axis of a building and the x- or y-coordinate; L_By_W is ratio of length of long axis and short axis of building; Group_ID is group identity code assigned in spatial partitioning. Shapes can be determined by Area and L_By_W; position can be determined by X, Y and Orientation. All of these five attribute allow the building object represented as point. The linking information is stored in an exterior table. For example, linking relations of buildings identified by 1~6 in LOD_B and building identified by 10 in LOD_S illustrated in Figure 1 can be stored in Table 2.

ID	X	Y	Area	Orientation	L_By_W	Group_ID
5	786	583	158.9	2.7	5.32	37

Table 1 Data structure of building object (ID stands for ID_LOD_S or ID_LOD_B)

ID_LOD_S	ID_LOD_B
1	10
2	10
…	10
6	10

Table 2 Linking information stored in exterior table

5.2 Flow chart of building typification

According to 'divide and conquer' if a condition holds in each part it also holds in the whole. Only typification in each cluster is considered (see steps wrapped in the broken rectangle in Figure 2). Given medium map scale M_X, LOD_X between LOD_S and LOD_B can be generated. Flow chart is illustrated in Figure 2. The typification procedure of buildings contains three steps. The first step is to determine the number of buildings in LOD_X using improved radical law. The second step is to determine the representation of new building in each cluster. The third step is to harmonize the size of buildings. In the second and third step every cluster is dealt with one by one.

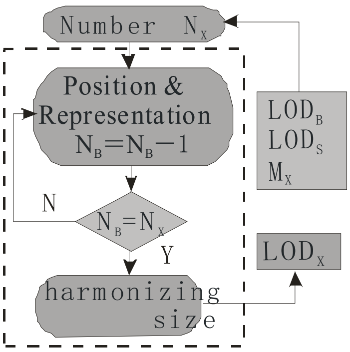

Figure 2 Flow chart of building typification

5.2.1 Number

There are a lot of methods to determine the number of new objects with respect to the request scale like Töpfer's radical law (Töpfer, F. and Pillewizer, W., 1966). Another approach is to keep the 'black-white' ratio between buildings and background constant for all scales (Wang JiaYao, etc.al. 1993). Improved Radical Law (Wang JiaYao, etc.al. 1993) is used here.

$$N_X = [N_B \sqrt{(M_B/M_X)^T}] \quad (1)$$

N_B is number of buildings in LOD_B; M_B is the denominator of scale of LOD_B; [x] is integral part of x. Difficulty is how to determine the selection level T. Numbers of buildings in LOD_B and LOD_S are recognized to satisfy the improved radical law, i.e.

$$N_S = [N_B \sqrt{(M_B/M_S)^T}] \quad (2)$$

N_S is number of buildings in LOD_S; M_S is the denominator of scale of LOD_S. Obviously T can be computed from (2).

$$T = 2(\lg N_B - \lg N_S)/(\lg M_S - \lg M_B) \quad (3)$$

That is to say as a parameter T can be deducted from implicit information in multi-scale databases. According to (3) and (1), numbers of buildings in medium LOD can be computed.

Principle of cartographic generalization is to keep the similarity during generalization, to keep the differences while reducing the differences (Wu Hehai., 1999). Improved radical law is built upon cartographic experience therefore is not adaptive to small area. In each cluster this law is not applicable or else uniformity trend would be visible between clusters with different density. Differences between clusters will be reduced but distinguished in such a certain degree that it will be not kept. On the other hand building density differences between groups are also need to be preserved. Solutions are given as follows: compute the building density of all groups firstly; if density differences are distinct groups will be classified into several homogenous classes. Selection level T is computed according to formula (3) in each class. If density differences between groups are obscure just one T for the whole map is computed. According to formula (1) number of buildings in each cluster in LOD_X can be determined.

5.2.2 Position and representation

The second step is to determine the representation of new buildings. This step iteratively reduces number of buildings and uses a most representative new building to typify the original two buildings in every cluster. Firstly the shortest distance between buildings in cluster is sought. A new building emerges and two correspondent buildings disappear. Its position(X, Y) is the midpoint. Its orientation and L_by_W is the average. However, in order to preserve local character its area are computed as follows: If size difference between the original two buildings is considerable, i.e. one is two times or more than another, the bigger area is adopted; or else average is adopted. The new building is added into next shortest-distance-seeking process. Number of buildings in each cluster is reduced by one after each iteration (N_B = N_B-1) until it equals the number computed in previous step ($N_B = N_X$).

5.2.3 Harmonizing size of building

The third step is to harmonize the size of buildings considering the minimal separate distance (MSD) of building itself and the preservation of differences between buildings (Regnauld, N.,2001) .Harmonizing function is defined as follows:

$$f(x) = \begin{cases} A_{msd}, & x \le A_{msd}; \\ x \cdot (A_{\max}/A_{\max}), A_{msd} < x < A_{\max}; \\ x, & x = A_{\max}. \end{cases} \quad (4)$$

x is area (size) of each building; A_{msd} is size of rectangle whose length and width are MSDs on the generalized map; $A_{\max}$ is size of the biggest buildings in the same cluster. After size harmonized each building would be legible and meanwhile differences between them are also preserved.

5.3 Theoretical Analysis and Discussion

Although theoretical framework is very clear the algorithm is still on the progress. Suggestions and discussions are appreciated. A lot of works have already shown its feasibility. This algorithm integrates multi-scale databases and on-the-fly generalization properly for easier on-demand cartographic information delivery in the context of web mapping. It also utilizes strategy of 'divide and conquer' and the cardinality comes to be 1: n and then the linking relation between building objects can not be divided any longer. Because it transforms the scope of building typification from the whole map space into cluster unit such that the algorithm is simple and effective and easier to be implemented. The algorithm can preserve relative density of buildings and is in accordance with the principle of cartographic generalization, i.e. 'preserving differences while reducing differences' (Wu Hehai., 1999). It can also preserve building alignment between clusters. One point that needs to be aware is that when determining the number, position and shape of buildings in medium LOD_X, LOD_B need to be given more priority and LOD_S is used to assist and speed up the whole process. On the one hand, more information can be sent to users; On the other hand, this complies with the definition of generalization.

However this algorithm also has its disadvantages. Firstly, a lot of jobs need to be done during the data-preprocessing phase and need support of GIS platform. Secondly, the spatial clustering method depends greatly on the original data distribution and sometimes it can not provide good matching results. Then evaluation and manual correction of clustering results is necessary. Thirdly, only minimal separate distance of building itself is considered in this algorithm but MSD between buildings is not included. Spatial conflict may emerge in dense area. At last building alignment inside every cluster is not preserved and relations between roads and buildings are neglected during generalization.

6. CONCLUSIONS AND POSSIBLE IMPROVEMENTS

6.1 Conclusions

How to generate web map that meeting user request rapidly is a very popular research issue in the field of real-time web mapping. Since automatic cartography generalization is not well done today, the idea of integrating multi-scale databases and on-the-fly generalization is significant and realistic. Adopting this idea as guiding principle this paper focuses its research on rapid algorithm of building typification in the context of web mapping. This approach nowadays seems to be well recognized strategy for on-demand map information delivery whether for web mapping and paper products [see research plan in Gemure, GiMoDig, and GENDEM]. And special attention and intensive research is needed in this area.

6.2 Possible improvements and future work

One of the possible improvements is the choice of clustering method in order to make linking relations between different LOD be in accordance with character of geographic landscape. Beside this linking relations can also be constructed hierarchically in real time by dendrogram or other methods.

My future work in the field of web mapping may contain several aspects:

1. Carrying forward this integrating approach to other features.
2. Borrowing new ideas from computer graphics like mesh morphing or progressive meshes. For example point clusters in different LOD can be built as two dimensional triangular meshes and then parameterized into one domain. Feature state on the medium LOD can be acquired be means of adjusting parameters and simple linear interpolation such that adaptive or intelligent zooming of web map is supported.
3. User profiles and a collection of illustrative plates need to be specified to establish building-blocks of web maps for users in different field and different hierarchy.
4. Progressive cartographic generalization and progressive vector transmission will be given highest priority.

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8. ACKNOWLEDGEMENT

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