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RECOGNITION OF ROADS IN AN URBAN MAP BY USING THE TOPOLOGICAL ROAD-NETWORK

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ABSTRACT

In this paper, we propose an experimental method to recognize roads from an urban map on the basis of the road-network. The road-network is a conceptual graph to represent connective relationships among roads. The first step in our recognition procedure is to construct this road-network approximately by the bottom-up method, as an application of image processing techniques. Then, the next step is to modify and complement this road-network exactly, based on both the heuristic knowledges for urban maps and the consistent/inconsistent interpretations for the road-network itself, from a top-down point of view. Such an approach integrated cooperatively with the top-down and bottom-up methods makes it successful to recognize roads in comparison with many traditional bottom-up oriented approaches. Also, we confirm our approach through some experiments.

1. Introduction

Today, it is one of important issues to compose the databases from various map data (e.g. urban maps, geographic maps, etc.) effectually with a view to offering many information services. Such information service systems are generally called Geographical Information Systems (GIS)[1]. The geometric relationships among roads in a map, which we call the road information, are the most fundamental items for GIS. It is not easy to accumulate the road information into computers economically, because the data composition procedures of human beings require extravagant times and much work. Additionally, the data precision is too low. Therefore, it is desirable to extract the road information automatically from a map with computers. However, the roads are not only overlapped complexly with the other items such as names of remarkable items, rivers, building symbols and so on, but also intersected with each other. At least, the automatic extraction of roads from maps is one of difficult subjects in the present.

In this paper, we propose an experimental method to extract the road information automatically from an urban map on the basis of the road-network. The road-network is a conceptual graph to represent the road information in the urban map topologically. In our approach, this road-network is firstly generated by the bottom-up method, and then is modified interpretively by the top-down method. After identifying the intersections from an urban map, the procedure composes the road-network by searching the roads from each intersection. Next, it modifies the road-network by interpreting the original urban map and the network simultaneously with heuristic knowledges about the urban map.

2. Extraction of Road Information

The extraction problem of the road information from an urban map is an active research subject and many reports have been already published : the method of chasing the sequence of parallel pixels in the image[2]; the method using the parallel vector tracer[3]; the skipping scan method[4]; and so on. Although these researches reported the partial solutions, they are not necessarily successful. This is because they are the bottom-up approaches, which are based only on the image processing techniques, using the local information about urban maps. In comparison with these methods, our method is more successful since the top-down approach on the basis of the model-driven method can refine the road-network interpretively, which was composed locally by the bottom-up approach. Our recognition process for roads is mainly divided into two phases : one is the bottom-up process to construct a basic and incomplete road-network from an urban map; and another is the top-down process to modify and complement the network, with the interpretation based on heuristic knowledges about the urban map and the network. We show our conceptual framework in Fig.1.

Our recognition procedure is practically composed of several routines as follows :

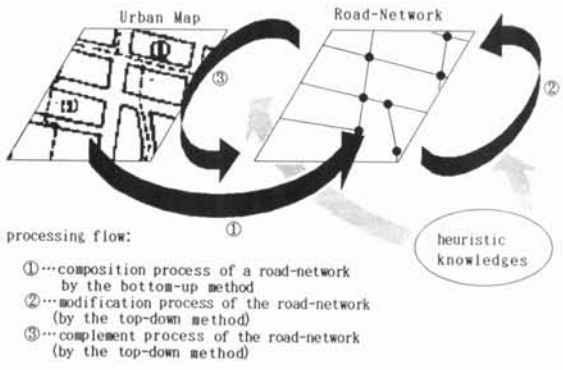

Fig.1 The overview of our framework

1). identification of intersections from an urban map;

2). extraction of pairs of parallel straight line segments;

3). search of roads along pairs of parallel straight line segments from individual intersections;

4). composition of road–network;

5). detection of inconsistencies for the road–network;

6). modification of the road–network with heuristic knowledges;

and

7). complement of the road–network by interpreting the original urban map with heuristic knowledges.

Here, the routines in 1) ~ 4) are controlled in the bottom–up approach, while the ones in 5) ~ 7) are in the top–down approach.

3. Composition Process of Road–Network

The road–network is a topological graph for representing the road information in an urban map. The nodes correspond to characteristic points such as intersections, terminal points of roads and connection points among neighboring roads. While, the edges indicate the connective relationships among nodes. This road–network is firstly composed in the bottom–up method, which analyzes the originally digitalized image data directly, and also takes a role of the road model in the top–down method. Of course, the road–network composed from the first data–driven process is insufficient as the model of an urban map. Therefore, the second model–driven process is necessary to refine its own road–network, in addition to the interpretation of the urban map.

In this section, we address the bottom–up approach to compose the road–network, first.

3.1 Preprocessing

A main task in the preprocessing is to extract candidate lines as road edges. Straight line segments with ℓ_0 or more pixels are selected from many lines which were applied by the thinning procedure and straight line approximation procedure (ℓ_0 : predefined constant). All of these selected straight line segments do not always correspond to the edge lines to represent roads because several kinds of compositive map elements are included in urban maps. Hereafter, we look upon the digitalized binary–images of these straight line segments as the processing objects.

3.2 Identification of Intersections

Next, the procedure identifies road edges and intersections to be primitive elements of our road–network. The former is to find out the neighboring pairs of parallel straight lines from candidate lines so that the threshold values for the width are from w_0 to w_1 (w_0, w_1 : constants). While, the latter first corresponds to extract the crossing tuples of non–parallel straight lines under the following conditions :

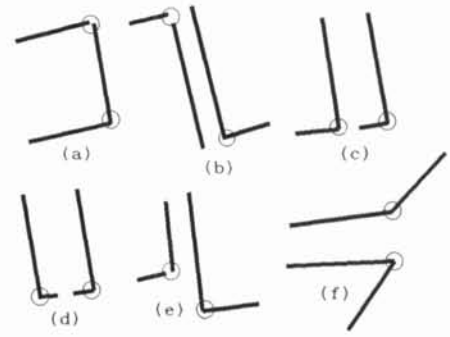

Fig.2 Typical instances inappropriate to a part of the intersection

[Cond.1] The angle θ constructed by 2 straight line segments : $\theta_0 \leq \theta \leq \theta_1$ (θ_0, θ_1 : constants);

[Cond.2] The shortest distance d between 2 terminal points of these non–parallel straight lines : $d \leq d_0$ (d_0 : constant).

Second, in order to identify intersections exactly, it is necessary to merge their crossing points with the next conditions :

[Cond.3] The distance d between two crossing points : $d_1 \leq d \leq d_2$ (d_1, d_2 : constants);

[Cond.4] Both of two crossing points share the same straight line segment;

[Cond.5] The geometric shape illustrated by their two crossing points is not one of shapes as illustrated in Fig.2.

3.3 Extraction of Parallel Straight Lines

In the composition process of our road–network the third task is to connect individual pairs of parallel straight line segments as one road. This task is performed under the following conditions because the parallel straight line segments extracted in the preprocessing task are not always components of roads, including the fragments of the others :

[Cond.1] The distance d between 2 centers of gravity of R_i and R_j : $d \leq d_3$;

[Cond.2] The angle θ constructed by 2 center lines of R_i and R_j : $\theta \leq \theta_2$;

[Cond.3] The length of the perpendicular h_{ij} or h_{ji} : h_{ij} or $h_{ji} \leq h_0$;

[Cond.4] The difference of the width w_i in R_i from w_j in R_j : $dw \leq dw_0$ $\quad (dw = |w_i - w_j|)$

Here, d_3, θ_2, h_0 and dw_0 are predefined constants. These conditions are shown in Fig.3.

3.4 Composition of Road–Network

The final task is to compose the road–network on the basis of parallel straight lines and intersections. This composition routine combines all parallel straight lines to appropriate intersections along the extensible directions of parallel straight lines connected to individual intersections. Namely, the starting points in the search pro-

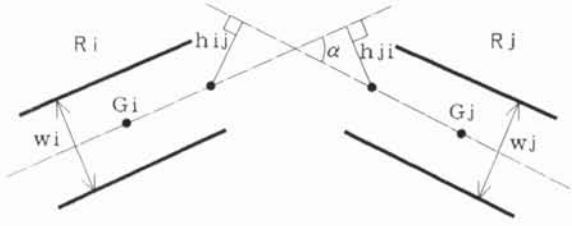

Fig.3 Connection of parallel straight line segments

cedure are intersections. The road–network consists of nodes, which are mainly derived from intersections, and edges, which correspond to parallel straight lines. Thus, our topological road–network is generated from the digitalized image map, by means of the bottom–up approach. We call this network the initial road–network.

4. Modification and Complement Process of Road–Network

The initial road–network generated by the bottom–up approach does not always represent practical roads in an urban map sufficiently. Therefore, this initial road–network must be refined so as to be able to represent many correct roads. This process modifies and complements the initial road–network with interpreting the road–network and the urban map simultaneously on the basis of heuristic knowledges. This reconstructed road–network is called the modified road–network. Our heuristic knowledges are classified owing to their usages as follows :

- as for the road–network,
  1. There is a +–shaped junction whose intersection has 4–way different directions;
  2. There is a T–shaped junction whose intersection has 3–way different directions;
- as for the urban map (our processing object),
  3. It is possible that T–junctions may be parts of +–junctions;
  4. It is, in general, certain that many roads in urban maps do never break short except for the map margins;
- as contradictions for the network organization,
  5. If the edges of the road–network and the straight lines which are parts of the road edges cross mutually, such a relationship can be regarded as a contradiction.

5. Combination Process of Road–Networks

Various widthes of roads are observed in urban maps (e.g. narrow, intermediate and broad ones). It is difficult to extract them at the same time, under the same threshold value. Therefore, our road–networks are constructed by 2 ways, depending on the road width : one is applied to roads of narrow –to– intermediate width, and another is to roads of broad width. After each extracting, these networks are combined. Such a combined road–network is the final road information in our recognition procedure.

6. Experiments

The urban maps drawn in the scale 1:10000 are digitalized by the image scanner with the rate of 10 pixels per millimeter and 256 gray levels. Next, they are converted into binary–image data : dark bits to foreground components and bright bits to background ones. Fig.4 shows a binary–digitalized image data (500 × 500 pixels). Such image data are input ones for the preprocessing, and called the source image data, here.

Initial road–networks composed by the bottom–up approach are shown in Fig.5 for narrow –to– intermediate roads and Fig.6 for broad roads. In comparison with that in Fig.4, we can see the insufficiency of bottom–up method in both figures. Fig.7 shows a modified road–network reconstructed from Fig.5 from a top–down point of view, while Fig.8 shows a modified one from Fig.6. Much of insufficiency shown in Fig.5 and Fig.6 will be improved by applying the top–down method. A finally modified road–network derived from the source image data (after the combination process among two road–networks in Fig.7 and Fig.8) is shown in Fig.9, corresponding to Fig.4. The road map in Fig.10 is a pretty reorganized road picture as the final output of our recognition result. At least, we can conclude that our method is successful. However, it is clear that all the roads in sample source image data are not identified. This is partly because in some cases the extraction of all intersections to be observed in the urban map ended in failure.

Fig.4 The source image data

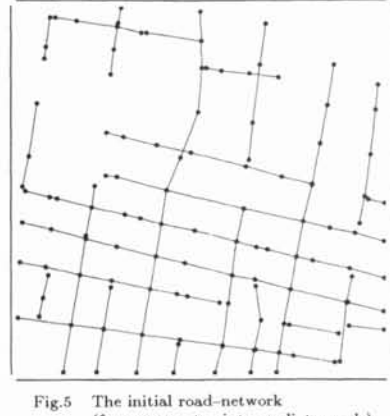

Fig.5 The initial road–network
(for narrow –to– intermediate roads)

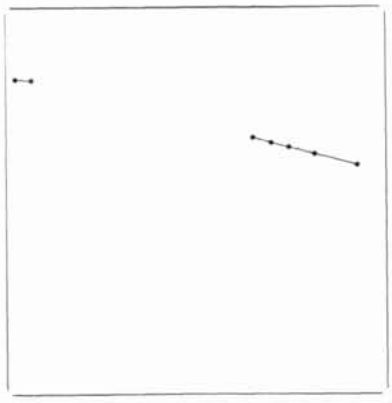

Fig.6 The initial road-network (for broad roads)

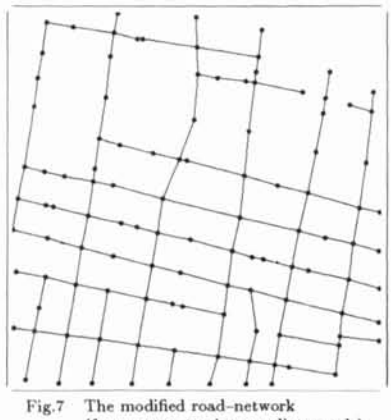

Fig.7 The modified road-network
(for narrow -to- intermediate roads)

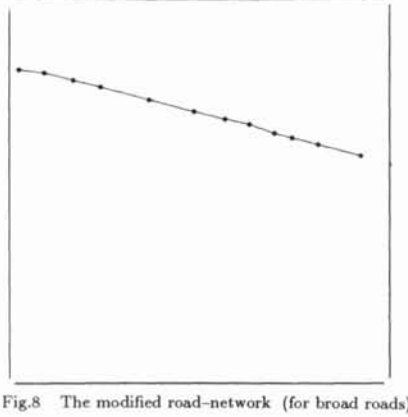

Fig.8 The modified road-network (for broad roads)

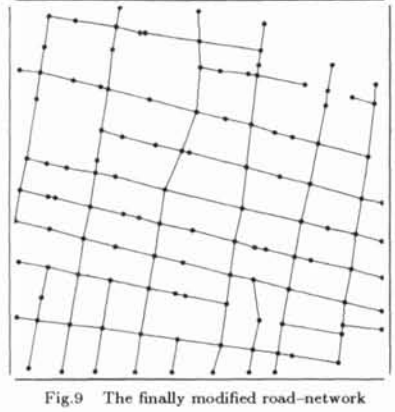

Fig.9 The finally modified road-network

Fig.10 The recognized road-map

7. Concluding Remark

In this paper, we described the method to extract the roads from an urban map automatically. The framework is composed of 2 different stepwise approaches : the first is to compose the corresponding road-network from the map on the basis of the bottom-up approach; and the second is to modify the network by interpreting and verifying with heuristic knowledges on the basis of the top-down approach. The complementary relationship between the bottom-up and top-down approaches characterizes our method.

However, many problems are imposed in the future. For example, the extraction ratio of roads from urban maps depends on that of intersections, currently. Furthermore, the reasonability and correctness for our heuristic knowledges are not investigated sufficiently and completely. To find out some solutions for such subjects makes our method more excellent.

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