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An Automatic Extraction of Road Information on the Basis of Cooperative Hypotheses Interpretation Mechanism

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Abstract

Many methods/approaches about the extraction of road information from map images have been proposed until today. In comparison with these currently developed methods/approaches, our approach supports a cooperative interpretation mechanism among simultaneously generated hypotheses. Namely, many of currently proposed approaches are based on the local refinement process for the existing road information, while our approach provides a paradigm to support a global refinement process: to check up inferable/interpretative modification means simultaneously; and to select the most reasonable modification means cooperatively among related interpretations.

1 Introduction

The subject about the automatic extraction of road information from map images has been recognized as effectual means to construct GIS(Geographic Information Systems) and various types of information systems. Many researches[1]-[8] were reported with respect to this subject. However, it is not always easy to accomplish this subject successfully because roads are, in general, overlapped and interrelated with other map components complicatedly.

In this paper, we propose an experimental approach to extract road information from urban map images. The characteristic in our approach is to refine road information on the basis of cooperative hypotheses interpretation mechanism. Most confident hypothesis is selected from many hypotheses by interpreting the mutual relationships among them. Namely, the disjointed roads caused by the existences of other map components such as building names, street names and so on, are connected as a result of inferring roads cooperatively from individually disconnected points.

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2 Approach

Until today, many approaches/methods have been proposed, concerning this subject. For example, the method for tracking parallel and continuous pixels[1], the skip-scan method[2] and so on were typically developed. However, since these methods were based on only the bottom-up approach, which interprets map images directly, the processing capabilities were limited.

On the other hand, the methods based on the top-down approach also were proposed:

1. Method based on the combination of bottom-up and top-down processings[3].
2. Method based on the cooperation among bottom-up and top-down processings[4].

In the combination method, the bottom-up processing is first applied to urban map images in order to extract the road information and then the top-down processing is used to refine the locally extracted road information globally with road network model. Here, the road network is a topological graph for expressing road information, and is composed of nodes and edges: nodes indicate characteristic points such as intersections, terminal points and so on; and edges point out the connectivities among nodes. We show a road network in Figure 1. While, in the cooperation method, the bottom-up processing and top-down processing are controlled repeatedly with respect to the refinement of road information.

However, it is not easy to distinguish roads from urban map images completely even if these advanced methods were applied. This is because the refinement process is too simple and is also applied without checking out the constructive relationships among neighboring areas. Namely, the hypotheses in this refinement process are first generated after checking the adjustment between the heuristic domain knowledge about road configuration shapes and the locally extracted road information one by one. Thus, the verification process of hypotheses is sequentially performed. The hypothesis is generated from only one disjointed point in road network and only one check point is corresponded independently with constraint conditions of road con-

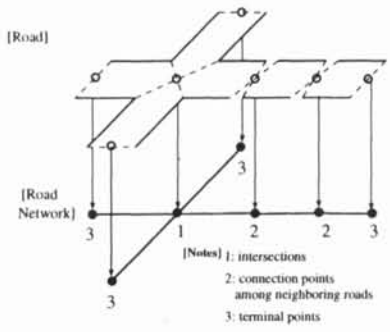

Figure 1: Road network

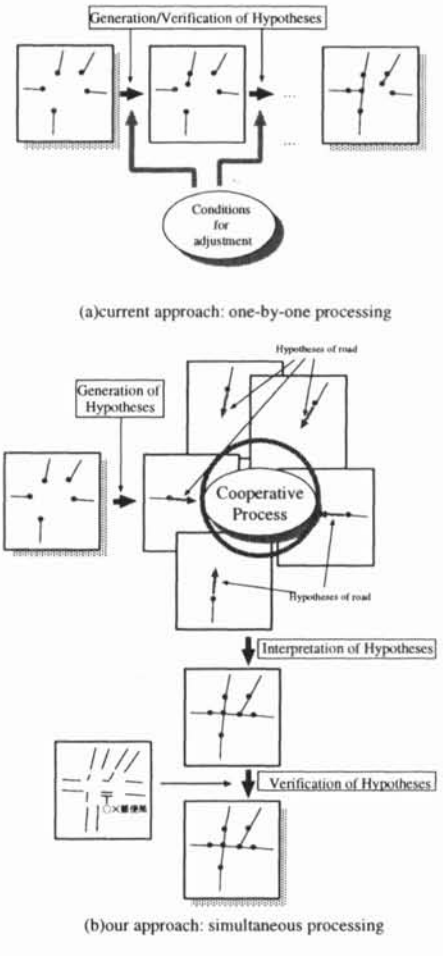

Figure 2: Our approach and current approach

figuration. The relationships between individually disjointed points are ignored. Also, the conformity, consistency and adequacy among individual hypotheses are disregarded. From these discussions we call this refinement process the negative mechanism in the fact that in these traditional approaches the hypotheses should be established only by their own valid evidences without depending on the complementary relationships among other hypotheses.

While, we propose the positive mechanism for this negative mechanism. In our positive mechanism, several hypotheses are generated from individually disjointed points simultaneously. The conformity, consistency and adequacy among these hypotheses are checked to select reasonable hypotheses; and then the road information is modified with a well interpretation to be inferable from selected hypotheses. Although the negative mechanism which checks the disjointed points one by one cannot always identify sufficiently the situation that a road is not straight or that roads are interrelated under other map components, the positive mechanism based on the cooperative judgement and global interpretation works well even on such a situation. Figure 2 compares our approach with current approach imaginally.

3 Positive Mechanism

Our positive mechanism is composed of three processes: generation of hypotheses; interpretation of hypotheses; and verification of hypotheses. And, the characteristic is that several hypotheses generated simultaneously are interpreted cooperatively so as to make up the most reasonable road construction.

3.1 Generation of hypotheses

The road network which represents road information with nodes and edges is generated through the connection procedure of different pairs of parallel line segments sequentially since a continuous road is looked upon as a sequence of pairs of parallel line segments[3][4][8]. However, this road network composed only in the bottom-up process does not represent the roads in the corresponding urban map completely. Many disjointed points exist in this road network because of the existence of other map components. We regard the following characteristic points as disjointed points in the generation process of hypotheses:

1. the terminal points in the road network(as shown Figure 1).
2. the connection points among neighboring roads in the road network only if the distance between two pairs of parallel line segments is larger than d_0(as shown Figure 1). Here, d_0 is the threshold value.
3. the both side points of a pair of parallel line segments which is not connected to any other ones in the bottom-up process.

The generation of hypotheses is to presume the roads which lead on the tip of the disjointed points on each road. The edge of l_0 in length, which we call TE(Temporary Edge), is generated toward an extensible direction of the road from each disjointed point. And, the direction is calculated with vector information on the edge which is adjacent to the disjointed point.

3.2 Interpretation of hypotheses

A temporary edge is a hypothesis for representing the presumed road. First, a pair of temporary edges which may express the same continuous road is extracted from a set of them. It is considered that two different temporary edges TE_i and TE_j represent the same road when they satisfy either of the following relations and make a pair of nodes disjointed points of TE_i or TE_j.

- Relation1: Opposite
  When two temporary edges are extensible to opponent's disjointed points mutually, the relation between these two temporary edges is opposite.
- Relation2: Intersection
  When two temporary edges are caught as a segment and crossed mutually, the relation between these two temporary edges is intersection.

However, each disjointed point is not corresponded by the 1:1 relation in the area where two or more roads interrelate mutually. In this case, as the second step, it is appropriate to treat only individually related node pairs together and necessary to understand geographical shape in this area. The hypothesis for road existence is set up between two disjointed points with the relation of opposite in the beginning, and then between two ones with relation of intersection the hypothesis is corrected under pregenerated hypothesis. Finally, the interpreted hypothesis is reflected on the road network. This road network is called a partial road network.

3.3 Verification of hypotheses

The valid fact whether such interpreted hypothesis is really true or not depends on the original map. Thus, the hypothesis must be always verified by a source map image immediately. Namely, it is examined whether the pixel row for indicating the road segment on both sides of the edge which is the component of a partial road network.

4 Experiment

Here, we show the effect of our approach through some experiments. The original urban map of scale 1:10000 is digitalized by the image scanner with 300 dpi and 256 gray levels. Figure 3 is a binarized urban map image(600x600 pixels).

Figure 4 shows an initial road network. This road network is constructed in the bottom-up process. On the other hand, Figure 5 is the finally refined result based on our approach. Additionally, Figure 6 shows the disjointed points where hypotheses are generated in the hypothesis generation process, and Figure 7 shows the reasonable disjointed points which are well inferable in the hypothesis interpretation process. When we compare Figure 5 with Figure 4, we can find the difference of 16 marked points. Through this experiment, we confirm that our cooperative interpretation process is useful for extracting automatically the road information.

Table 1 shows the recognition result for other map images. The numeral in each block indicates the number of roads(or edges). And the numeral in each parenthesis indicates recognition rate individually based on the bottom-up approach and our proposed approach.

Table 1: Recognition result

	Source	Initial-net	Final-net
MAP1	133	97 (72.9)	119 (89.5)
MAP2	148	122 (82.4)	138 (93.2)
MAP3	119	96 (80.7)	108 (91.0)
MAP4	144	105 (72.9)	118 (81.9)
MAP5	146	99 (67.8)	115 (78.8)
SUM	690	519 (75.2)	598 (86.7)

5 Conclusion

In this paper, we proposed the cooperative hypothesis interpretation mechanism to extract road information automatically from urban map images. This mechanism makes it possible that inferable/interpretative disjointed points, which are not always connected well in the traditional methods/approaches, are connected mutually by global configuration near to the disjointed points. And, our experiment made it clear that our mechanism is very applicable and the extraction effect is good. As our near future work, we must improve this cooperative hypothesis interpretation under the introduction of various relations in addition to two relations "opposite" and "intersection". This is because we can observe that some disjointed points are not identified in Figure 5.

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Figure 3: An urban map image

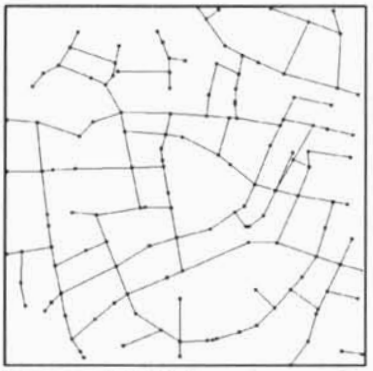

Figure 4: Initial road network

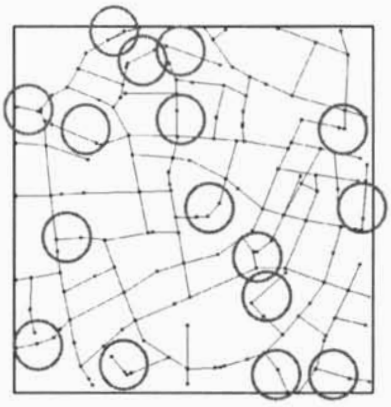

Figure 5: Finally refined road network

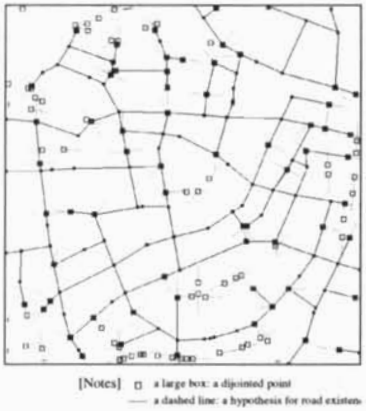

Figure 6: Generation result of hypotheses

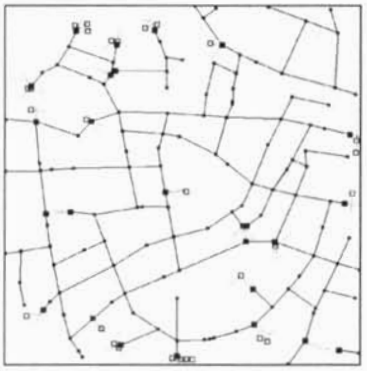

Figure 7: Interpretation result of hypotheses