

# Directional texture information for connecting road segments in high spatial resolution satellite images

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**Abstract**— This paper addresses the use of directional textural information for connecting road segments. In urban scene, some roads are occluded by buildings, casting shadow of buildings, trees, and cars on streets. Automatic extraction of road network from remotely sensed high resolution imagery is generally hindered by them. The results of automatic road network extraction will be incomplete. To overcome this problem, several perceptual grouping algorithms are often used based on similarity, proximity, continuation, and symmetry. Roads have directions and are connected to adjacent roads with certain angles. The directional information is used to guide road fragments connection based on roads directional inertia or characteristics of road junctions. In the primitive stage, roads are extracted with textural and direction information automatically with certain length of linearity. The primitive road fragments are connected based on the directional information to improve the road network. Experimental results show some contribution of this approach for completing road network, specifically in urban area.

## I. INTRODUCTION

With the advent of high spatial resolution satellite imagery, the interest of automatic extraction of artificial topographic features has been increased rapidly. This is stimulated by the needs for efficient mapping and updating data for Geographic Information Systems [1]. Automatic extraction of roads networks is one of the important issues among them. For this, a number of studies have challenged for extraction of road networks from remotely sensed data. However, any method of algorithm cannot yield satisfactory result yet [2]

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imagery is generally hindered by them. The results of automatic road network extraction will be incomplete. To overcome this problem, several perceptual grouping algorithms are often used based on similarity, proximity, continuation, and symmetry.

Zang et al. developed a method to complete road network using extension of parallel edges extracted from 2D image and 3D space [3]. When a rectangular region shaped by parallel edges was confirmed as salient road segment, the region was extended to an adjacent area along edges by examining any evidence that can be a part of roads. Hinz et al. adapted several verification methods to connect discontinuous road network such as ribbon snakes, homogeneity, and by exploiting the context relations [1].

There are not robust methods to complete road networks yet in spite there are many researches on the issue. This study is one of the researches to build road network with more robust and more automatic methods. In this study, knowledge-based approach was examined without any human operating to fill gaps between road segments. This study developed a method in which human's input was minimized to assign several threshold values in the process to complete road networks.

This study is focusing on a monocular image to find road networks.

## II. THE PROPOSED METHOD

Roads have directions and are connected to adjacent roads with certain angles [4]. The directional information is used to guide road fragments connection based on roads directional inertia or characteristics of road junctions. In the primitive stage, roads are extracted with textural and direction information automatically with certain length of linearity. The primitive road

fragments are connected based on the directional information to improve the road network.

The major characteristics of roads are their geometric shape and spectral homogeneity locally. Roads in high spatial resolution images in urban area show geometrically linear and spectrally homogeneous characteristics. Those are good clues to start to trace roads in urban area. The point is how the starting points or regions can be identified. In totally automatic approach to trace roads, road tracing algorithm itself can search and decide the starting points or regions without human intervention or assume that there is no map information. This study assumed that there is no geospatial information except the image used in this study. It also persuaded that human interventions are minimizing for completely automatic method. The process in the suggested method consists of three major parts, which are defining masked area, finding seed area for road network tracing, and region growing to identify road areas and networks.

#### *A. Defining masked area*

In the first stage of the process, the areas that would have very low possibilities of roads were eliminated. The areas were assumed that shadow and vegetation area could not be a part of roads. For shadow areas have some possibilities of a part of roads. However, some of shadow areas should not be a part of roads. It is better to solve the interruption of road by shadow with other process. This approach has been used by several studies [5].

#### *B. Seed column for road network tracing*

Roads have some attributes that includes linear shape and relatively homogeneous spectral characteristics. The spectral homogeneity of roads are more dominant in local area. This characteristic can be used to find a start point or region for road tracing. In this study, the parts of roads were extracted automatically without human intervention except assigning several thresholds. The threshold values were about the size of the linearity, the level of spectral homogeneity of one geographic features. The seed area for roads tracking was searched by linear shaped directional operators that can be defined as various sizes.

Directional texture operator exploited linear attribute of road [6]. The operators search all the possible directions by the size of operator. The strategy to find seed column for roads were that any directional operator had less than the

threshold for spectral homogeneity, then the pixels of the moment's operator was selected as a seed area. The seed columns kept their spectral statistics and directional information. The statistics and directional information was used for the next step to fill gaps of road segments to complete road network.

#### *C. Connecting Seed Columns and Region growing for road areas*

The interrupted road network was connected based on the directional information of seed columns. Various sizes of operators searched any similar directional columns within a certain range of area. When a size and direction column satisfied a given condition, the two points were connected with the column. It is difficult to identify the distance between any two pair of end points, and the direction of roads because the phenomena were very random. To overcome this problem, various sizes and diverse directions should be explored.

Even though parts of linear shape seed areas were identified, there should be some regions remained that surround the seed areas that are belonged to roads. These areas were explored by the region growing method. The first step of region growing is to check the range of the seed column's DN's for all bands used. The second step is that an adjacent pixel of the seed column was tested to the similarity judged by the range of the seed column's DN's. When the pixel under investigation satisfied the condition, the pixel was assigned the id of the seed column. This process was continued till the process did not find any other pixels that satisfied this condition. Then the seed column finding process was implemented to find next seed area and its surrounding region.

### III. AUTOMATIC TRACKING ROAD NETWORKS

Automatic tracking road networks were performed with IKONOS pan\_sharpened multispectral data that have 1 meter spatial resolution. A 1596 by 1572 meter area in Jeju, Korea, was selected for this study. IKONOS data from September 9, 2000 was available for this site. In Korea, early September is during summer, matured stage to leaf-out of the deciduous trees. Thus the imagery is with obscuring deciduous leaves, maximizing the occlusion of ground objects.

#### *A. Seed area by directional linear shape operator*

The seed areas can be searched for various directions and various sizes of operators. For the directions, it is difficult to identify the direction of a road before searching the direction. It should be needed to explore all the directions to identify road direction of a certain segment. However, it is not effective to search for all the sizes. The sizes of road segment would be different from segments. But important issue with this is to identify the linearity of road. Then, it is possible to reduce the range to check the linearity of road. In this study, 8 kinds of sizes of linear operators were adapted to the image data, which are 10 meters interval from 31 meters to 101 meters because these sizes of operators were considered to cover almost of linear shape roads. As shown in the results for four sizes of operators that are 101, 71, 51, and 31 meters (figure 1), the larger the size of the operator is, the more salient the linear shape of roads is. When the size of operator becomes smaller, the unexpected linear shape of areas were detected whereas the more road networks were detected by it. It is possible to choose a certain size of operator that is proper to a scene under investigate. In this study, the policy to figure out seed area contents was to give priorities on large size of operator. The searching results for the 8 sizes of operators were discarded or selected by the policy, and saved in a matrix.

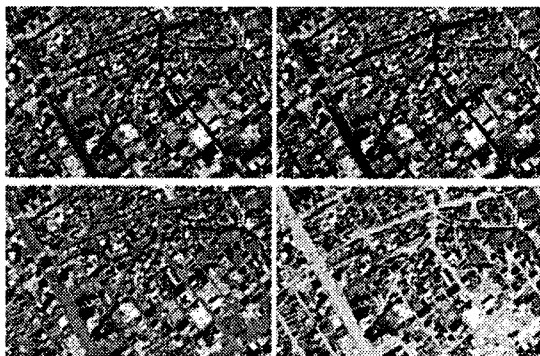


Figure 1. Seed areas searched by the suggested method. Upper left is about the result for 101 meter size operator, upper right 71 meter, lower left 51 meter, and lower right 31 meter result.

The results of the directions of operators give some important information to build road networks. Roads in well regularly organized urban area generally show some propensities of same directions. The lost part of road networks can be recovered when using this information. For this, each directional seed column was assigned its own ID, and was stored every information that was analyzed for the column. Among them,

directional texture information can be used for connecting road segments.

### B. Connection of road segments

The interrupted parts of road network was distinguished into two kinds in this study. The one is disconnection within a same direction of road. The other one is disconnection at perpendicular junction area. The method to confirm a former type disconnected parts of road network by this study was to identify a pair of ending points that had same direction. For this, when an end point of a part of road network was confirmed, operators search a correspondent point within a certain range. The interrupted parts of road network should be random and the size of the gap also should be various. When this operator is searching a correspondent point of the end point, the correspondent point should have a direction that should have similar direction within a certain range of threshold from the direction of the previous end point confirmed. The ranges of area and directions to search would be various. But the ranges should be proper for the scene because if the wide range is given, the result should contain noise connections that are not wanted. In this study, the range of search was 25 meters and the range of angle was  $\pm 5^\circ$  of starting point. The method to find a later type is almost the same as the former one except the characteristic of correspondent point. For later one, the correspondent point should have perpendicular direction against the end point. An example of the methods is shown in figure 2.



Figure 2. Incomplete parts of road network searched and connected by the suggested method.

### C. Region growing results

Seed areas were extended to adjacent areas using the range of the seed column under investigation. The ranges were different each other because the homogeneity of road areas were different from the location. The ranges searched were saved in a file with the ID of the seed

column. This way, the seed areas' homogeneity values can be used at any time needed.

Figure 3 shows the results of region growing based on the spectral statistics of seed columns by the suggested method. In the result of 101 meter operator, the major roads were well extracted. However, some of road networks were not depicted at this size of operator because the size of linear shape roads. For the 31 meter operator results, almost of the road networks were covered by this method even though there are some regions that are large structures that are not parts of roads and have similar spectral measurements from the small sizes of operator results.

The region growing was interrupted by occluded structures over roads, shadows, and vegetations such as street road trees. The region growing is extended to unwanted areas that are parking lots and some large buildings. Figure 3 shows that the disconnected parts of network was connected by this method. The lines were land parcel boundaries from land parcel map.

Large size of parking lots has sufficient size of area and similarity of spectral characteristics. Roads were interrupted by the parts of roads structures such as pedestrian crossing marks. Region growing for roads were also stopped by the cars on streets. Narrow roads were affected more than wide roads.

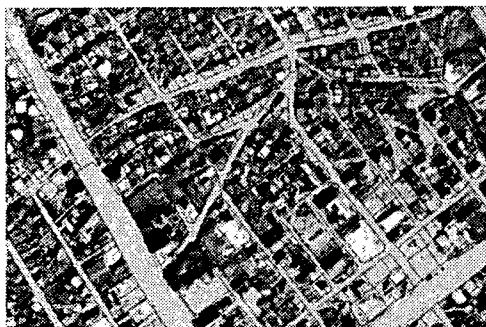


Figure 3. Region growing results by the suggested method result for 101 meter size operator.

The strong point of this region growing method is that region growing overcomes car occlusion that has little slit between cars that expose roads spectral characteristics even though there is some car occlusion on roads. This means that this method can bring better results for higher spatial resolution imagery.

Experimental results show some contribution of this approach for completing road network, specifically in urban area. It is needed to be careful to adapt the range of connection and direction angle similarity. The more loose the

condition is, the more the unwanted connections would be made.

#### IV. CONCLUSION

This study produced a knowledge-based automatic road networks tracking method specifically designed for high spatial resolution imagery. The seed columns for roads were searched without any human intervention except assigning few parameters. The incomplete road network was connected by the directional information of seed columns. The suggested method resulted in effective results to construct road networks. The results of this study imply that no human intervention methods to extract road networks showed more robust way. Another strong point of the suggested method is that region growing overcomes car occlusion when there is any little slit between cars that expose roads spectral characteristics even though there is some car occlusion on roads. This means that this method can bring better results for higher spatial resolution imagery.

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