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STRAIGHT LINE EXTRACTION BY CLUSTERING

Introduction

One of the important problems in an aerial image interpretation is a detection of human-made objects like buildings, roads and others to recognize them. Boundary of these can be described easily by a set of straight lines. The main task in this problem is an extraction of straight lines in the images to detect these objects and recognize them.

An overview of known techniques for straight lines extraction is given in [1]. We consider here three main algorithms for the task: the Nevatia-Babu method, the Burns technique and the Venkateswar-Chellapa approach.

The first method [2] is based on a convolution of an initial image with six 5x5 masks to extract contour pixels. The extracted contours are approximated by series of piecewise linear segments. This method is characterized by relatively large masks size, that leads to elimination of small-sized objects and merging closely situated lines together.

In the Burns approach [1], the image is convolved with two simple 2x2 masks to detect contour pixels. The extracted pixels with the same gradient orientation are then grouped. The obtained surface is approximated by a planar one. The straight lines are defined as intersection of a fitted plane with a horizontal plane. This method gives a qualitative result, but requires a big amount of operations to calculate approximation planes for each line.

In the third method [3], a contour image is scanned and each contour pixel is labeled by a label of line associated with it. The analyzed pixel is joined to a straight line under performance collinearity and connectivity conditions which are verified by using a number of samples prepared heuristically.

In this paper, we suggest the straight line extraction algorithm having simple implementation, which allows to increase quality and speed-up the straight line extraction process. We use a strategy of moving from contour image level to straight line image representation through intermediate level of primitive lines. The algorithm contains the following main stages:

- primitive line (PL) extraction which is mainly based on edge detection technique;
- extraction of straight lines from the PLs by using a cluster analysis.

I. Main notions

1.NEIGHBOURS. 4-neighbours of the pixel are its horizontal/ vertical neighbours. D-neighbours of the pixel are its diagonal neighbours. 8-neighbours of the pixel are the 4-neighbours and D- neighbours.

2.DIRECTIONS. An each edge pixel has its own direction. The edge direction is defined from the contour tracing clockwise. A zero edge direction is assumed for the pixel do not belonging to the contour lines.

3.LINES. The contour image has the following types of line. Primitive line is a set of 4-neighbour pixels in a horizontal or vertical direction. PL has horizontal, vertical or zero orientation. A zero orientation is an orientation of one-pixel length PL. A line segment is a line formed by PLs with the same features.

II. Primitive line extraction

To extract primitive lines, it is necessary to detect edges with one-pixel width by one of known algorithms.

The primitive lines are extracted by the edge line tracing. The tracing process starts from the end pixels and calculates the following PL characteristics: orientation, length, first and last PL pixels coordinates, and direction to the next PL (NPL). We use four possible NPL directions. They

are defined by a number of D-neighbours because two PLs can be D-connected only.

III. Extraction of line segments by using cluster analysis

We consider that the straight line is represented by a set of PLs (Fig.I). Orientation and NPL direction for each PL are the same within the line. However, some deviations in the PL length are allowed. Therefore, we can consider a straight line as a set of neighbouring PLs with the same orientation, NPL direction and approximately the same length. To extract line segments, it is necessary to find required sets of PLs among all PLs in the vector line description.

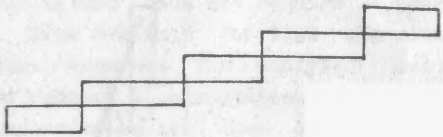

Fig.I. Straight line representation in a discrete image

To solve this problem, we use the cluster analysis method. It allows to join PLs into clusters corresponding to the line segments. Some straight boundaries at the image will be represented by almost straight lines with some deviations in straightness caused by noise. These deviations lead to necessity of additional cluster rules forming:

- PL with the NPL direction different from the others in the cluster is included in this cluster if it is not situated at the ends of line segment and has the same orientation.
- PL with another than the others orientation in the cluster is included in this cluster if it is not the last one and its length greater than a fixed threshold value V.

These heuristic rules reduce a noise influence on line straightness. The cluster forming process is organized by the tracing of records array. The neighbouring PLs with the same NPL and orientation belong to one cluster. The formed

cluster corresponds to the line segment. The end points of the line segment are first point of start PL and last point of last PL in the cluster. The end points extraction technique produces isolated line segments.

Usually it is necessary to join the line segments to obtain a real geometric figure. For this aim, a connection between end points of line segments should be established. That might be performed by different opportunities:

a) By the use of bridge line segment. The neighbouring end points of line segments are connected by bridge line segment (Fig.2.a).

b) By moving end point out of the cluster area. The end points of the line segment are first point of start PL and first point of the next line segment along the contour line (Fig.2.b).

a) b)

Fig.2. Establishment of connectivity between neighbouring lines

In the result, we obtain the extracted line segments represented by their end points coordinates.

IV. Straight line extraction

The straight line in a noisy image is usually represented as a set of connected and almost collinear short line segments. Then, it is necessary to extract an initial straight line with simultaneous its smoothing.

For any pair of connected line segments, the deviation of line segments from a hypothetical line is calculated (Fig.3.).

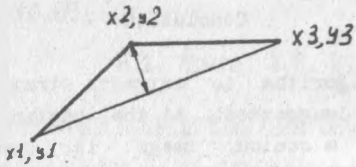

Fig.3. On the line smoothing process

When the deviation is less than a given threshold S, the smoothing is performed by creating a new line part with xI, yI and x3, y3 coordinates and by removal the initial line segments. This operation is performed until the line is changed. Since the line segments are calculated by the contour line tracing, the neighbouring line segments are situated at the neighbouring positions in the vector representation. Therefore, our method does not require a search of candidates among all line segments for line extraction. Only previous and next line segments for analyzed one are examined and processed. It reduces a computational cost of the algorithm and gives its complexity as less than O(n) where n is the number of the line segments.

V. Experimental results

The software realizing this approach has been developed in C language.

The input gray-scale images are obtained from aerial photographs. The digitized images have 256 gray-levels. The computation time to extract the one-pixel width contour line is equal IO sec on IBM PC AT 386/387 computer with 40 Mhz frequency. The process of vector line description with line segment extraction takes 50 sec and the straight lines are extracted in I sec.

The initial contour image included I386 primitive lines. The number of extracted straight lines becomes equal 595 at the image. After noisy lines with a length less than 7 pixels deleting a final quantity of straight lines in the image is equal to 92.

Conclusion

The fast algorithm to extract straight lines in aerial images has been suggested. At the beginning, for an initial gray-scale image, a contour image is computed. To detect one-pixel width lines, an approach based on computation of edge pixel direction is used. The primitive contour lines are extracted in the image and are joined into line segments by cluster analysis method. The algorithm to smooth the line segments and eliminate noisy lines in images has been developed. The developed method allows to achieve a good relation between a computational time and line quality.

References

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