International Journal of Computer Science and Engineering Communications
Volume.5, Issue.5 (2017): Page.1730-1734
www.ijcsec.com

Curve Extraction Using Minimal Path Propagation Backtracking and Hough Transform

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Abstract :*This paper proposes an approach termed minimal path propagation with backtracking and hough transform. It was found that the information in the process of backtracking from reached points can be well utilized to overcome the problems faced in existing methods and improve the extraction performance. The whole algorithm is robust to parameter setting and allows a coarse setting of the starting point. Minimal path techniques can absolutely delineate geometrically curve-like structures by finding the path with minimal accumulated cost between the endpoints. Curve extraction have found wide practical applications such as line identification, crack detection, and vascular centerline extraction.*

Keywords - *Curve-like structure, hough transform, centerline, minimal path tracking, backtracking, endpoint problem, shortcut problem, accumulation problem.*

I. Introduction

Minimal path techniques can efficiently extract curve-like structures by finding the optimal and integral minimal-cost path between two points [1].Successful applications of minimal path techniques have been found in contour completion [2] , tubular surface segmentation, vascular centerline extraction, skeletonization , and motion tracking. Minimal path techniques are fast and can avoid local minima by efficiently finding the global energy minima. The minimal path techniques can effectively locate tiny vessels and overcome vessel crossing and inhomogeneous intensity distribution in presence of stenoses or image degradations. However, some basic problems noticed for these minimal path based techniques are: 1)endpoints must be defined by user with enough accuration in each line of interest [3](endpoint problem), 2) the link might fail when the geodesic distance between the two points is much smaller than the expected minimal path (shortcut problem), 3) for two distant points, the search for minimal path tends to become inefficient as the cost gathers during the propagation with an increasing risk of leakage into some other regions (accumulation problem). Major importance is given to addressing these three issues with complex topologies (i.e. multiple branches or lines), noise and inhomogeneous contrasts.

Lines, circles or other parametric curves can be detected with the Hough transform (HT) . It was used since 1962 (Hough 1962) and then to find lines in images a decade later. The goal is to find the location of lines in images. Morphology and a linear structuring element, or by correlation can be used to solve this problem. Then it need to handle rotation, zoom, distortions etc. If their parametric equation is known Hough transform can detect lines, circles and other structures. It can give robust detection under noise and partial occlusion.

In this study, we developed a solution termed Minimal Path Propagation with Backtracking (MPP-BT) and hough transform to face the three above problems. The MPP-BT[4] method first applies a minimal path propagation from a single starting point and then, at each intermediate reached point, traces back to the starting point with certain steps. Here, the original idea of "backtracking" can be found in the constraint satisfaction problems in computer science and graph theory which was proposed as a more better algorithm than the brute force enumeration in searching the solution using backtracking algorithms. But the "backtracking" in the proposed approach goes beyond the basic "tracking backward" method by fully utilizing the information on visiting preference and cost increments during this backtracking operation to give an overall effective structure extraction. An efficient stopping technique is built by evaluating the evolution of cost increments in backtracking during the propagation operation. It must be noticed that only a user-defined initial point is required for the whole structure delineation. An additional breakpoint-connecting operation and hough transform can extract the final complete curve-like structures can be obtained via Since hough transform alone cannot extract whole curve the combined effort extract it efficiently to a particular extent. This paper organized as follows: Section I contains complete description about this paper, Section II includes the details of proposed method, Section III describes the conclusion.

II. Proposed Method

Minimal path methods extract curve-like structure in an image by searching the connected path with a contour dependent minimum integrated energy between two user preset points, a starting point and an end point. The block diagram of this system is shown in Fig. 2.1.As shown first input curve like structure is given to the system and minimal path propagation is performed using dijkstra's algorithm, then using hough transform and backtracking operation output curve like structure.

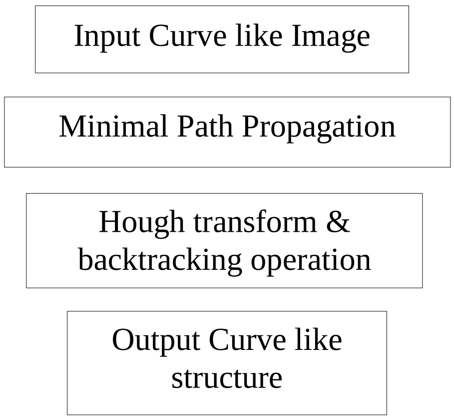

Fig. 2.1 Proposed System

As illustrated in Fig.2.2, if it trace back the minimal path from each reached grid point p to the starting point p_s, feature points (the points located inside the target curve-like structures) will receive much more revisits than non-feature points (the points located outside the target curve-like structures).

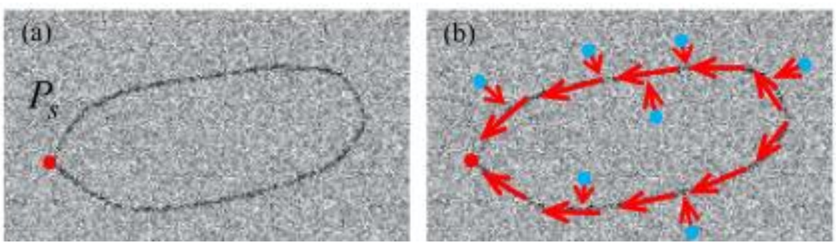

Fig. 2.2 Illustration of backtracking operation

This is due to the fact that feature points always have smaller cost values than non-feature points and the backtracked path is also the one with the minimal accumulated cost. In most time, such backtracking will reach feature points after some steps if the minimal path propagation is limited to the region around the target structures.

The data of visiting preferences and cost additions in such backtracking operation can be utilized to tackle the disadvantages pointed out in the previous paragraph. This algorithm is termed Minimal Path Propagation with Backtracking as illustrated in Fig.2.2, feature points (the points located inside the target curve-like structures) will get much more revisits than non-feature points (the points located outside the target curve-like structures) if it trace back the minimal path from each reached grid point p to the starting point p_s. This is due to the fact that feature points always have smaller cost values than non-feature points and the backtracked path is also the one with the minimal accumulated cost. In most time, such backtracking will reach feature points after some steps if the minimal path propagation is limited to the region around the target structures. This algorithm is termed Minimal Path Propagation with Backtracking (MPP-BT) and hough transform. This MPP-BT approach is detailed as below. First initiate the minimal path propagation with the Dijkstra algorithm from a starting point p_s . For each grid point p reached by the propagation front, calculate the cost value P(p) according to equation and then track l steps from point p backward the starting point p_s based on the connection information obtained in the previous minimal path propagation. The backtracking is stopped if the starting point p_s is reached before l steps. The minimal path propagation is controlled via a stopping strategy explained below to limit the propagation within the region around the target features. Hough transform does the basic operation of line extraction and other steps. The extracted curve-like structures of 2D crack and 2D vascular images were quantitatively evaluated with the manual results using the following four metrics:

$$TP= \frac{NB \cap NR}{NR} \quad (1)$$

$$FN= \frac{NR - NB \cap NR}{NR} \quad (2)$$

$$FP= \frac{NB - NB \cap NR}{NR} \quad (3)$$

$$OM= 2 * \frac{NB \cap NR}{NB + NR} \quad (4)$$

where TP, FN, FP are the metrics of true positive, false negative, and false positive, respectively, and OM is an overlap metric known as a Dice similarity coefficient. NR is the number of classified feature pixels determined by in the manual results as the ground truth reference, and NB is the number of the feature points extracted by the MPP-BT method. The OM index is equal to 1 when the reference and extracted curves can be exactly super imposed and 0 when they do not share any pixel.

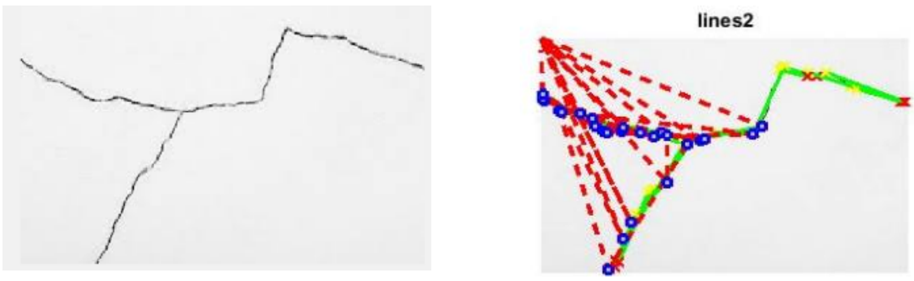

Fig 2.3 Input1 crack image

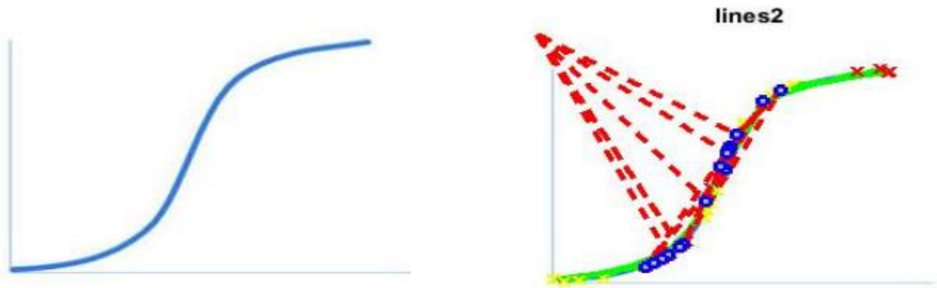

Fig 2.4 Input2 curve image

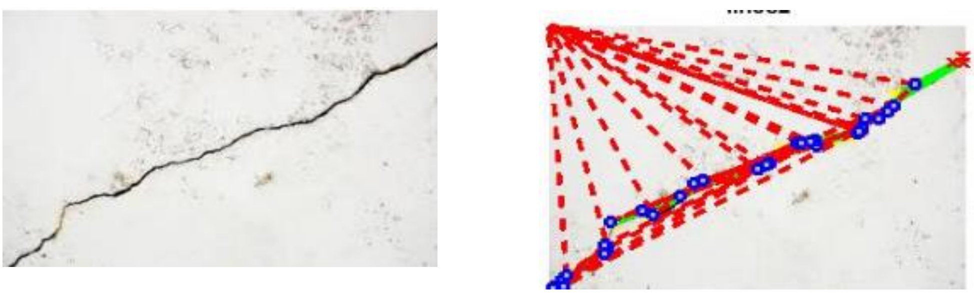

Fig 2.4 Input3 crack image

To quantify the extraction precision, TP, FN, FP and OM values calculated are listed in table 2.1 which include different metric values for different input images.

	1st input	2nd input	3rd input
TP	0.882	0.750	0.823
FN	0.117	0.251	0.176
FP	0.058	0.057	0.060
OM	0.937	0.827	0.875

Table 2.1

III. Conclusion

In this an approach termed MPP-BT with hough transform is developed based on the intuitive observation that feature points with low cost always receive much more revisits than non-feature points. Information on visiting preference and cost increments in this backtracking process is fully exploited to overcome the endpoint problem, the shortcut problem and the accumulation problem commonly encountered when using approaches based on minimal path tracking. The experiment results show that the proposed algorithm can provide effective extractions of curve like structures with only one roughly user-defined starting point.

Better results can be expected if the image quality can be improved by suppressing noise and artifacts in the images. They also show that a coarsely defined set of starting point works well for this MPP-BT and hough method. However, it was also noticed that the proposed method might fail in extracting some structures if there are obvious gaps between them. Some high contrast edges or artifacts also tend to increase false curve-like structures in the final extractions. Future work will be devoted to address all the above problems. It is also planned to extend the backtracking strategy to other segmentation or classification tasks.

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