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Survey on Curve Detection Algorithms

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***Abstract*—Techniques including minimal path can efficiently extract curve-like structures by optimally finding the integral minimal-cost path between two seed points. In the first method, a novel minimal path-based algorithm which works on more general curve structures with fewer demands on the user for initial input compared to prior algorithms based on minimal paths. The main novelties and benefits of this new approach are that it may be used to find both closed and open curves, including complex topologies containing both multiple branch points and multiple closed cycles without demanding pre-knowledge about which of these types is to be extracted, and it requires only one input point which, in contrast to older methods, is no longer constrained to be an endpoint of the desired curve but truly may be any point along the desired curve. The second method MPP-BT (Minimal Path Propagation with Backtracking) first applies a minimal path propagation from one single starting point and then, at each reached point,backtracks few steps back to the starting point. Researchers in different areas like geometric optics, computer vision, robotics, and wire routing have previously solved related minimum-cost path problems using graph search and dynamic programming principles.**

Keywords-Curve Detection; Minimal Path Propagation with Unknown end points; key points; accumulation problem; backtracking; stop propagation.

I. INTRODUCTION

Minimal path techniques find the integral minimal-cost path between two seed points[1] and extract curve-like topologies optimally. Minimal path techniques have found successful applications in contour completion[2], tubular surface segmentation [3][4],centerline extraction of vascular images ,skeletonization, and motion tracking.

Minimal path techniques are efficient and can avoid local minima by searching the global energy minima. Minimal path techniques can efficiently locate small vessels and tackles vessel crossing and inhomogeneous intensity distribution in presence of stenoses or image degradations. A technique called Minimal Path Method With Keypoint Detection (MPWKD) was proposed to find a curve using only one specified endpoint. This MPWKD technique finds representative key points along the target curve by a front propagation and stops the propagation process when a desired curve length is reached. This technique is limited in real applications since prior length knowledge is often hard to be effectively provided for complex topologies and scenes. To obtain a multiple branch dilineation without setting each endpoint, Li et al. found a 4D iterative key point finding scheme, in which the minimal action map and Euclidean length map were found via the freezing fast marching process. Later, a method with no endpoint requirement was proposed[5]. This method using the maximum Euclidean distance summation tracks a curve like structure by detecting the key points along the curve trajectory. Only one starting point lying in the target curve needs to be preset to get this curve but others must be specified in case of discontinuities. Later a propagation stopping criterion was built via evaluating the geographic distances in backtracking, and techniques aimed at handling false key points, circle disconnection and short-cut problems were also focused. However, even with these improvements, missing branches can still be observed .Some inherent problems can be noticed for the earlier minimal path based methods:

1) two endpoints must be defined by user with enough accuracy for each line of interest(endpoint problem), 2) the connection might go wrong when the geographic distance between two points is shorter than the expexted minimal path (shortcut problem), 3) for two distantly separated points, search of shortest path tends to become inapplicable as the cost sums up during the propagation with a high risk of leakage into non-relevant areas(accumulation problem). To address these three problems is of main importance in dealing with complex structures,noise and inhomogeneous contrasts.

In the second paper, a solution for solving the above mentioned three problems termed Minimal Path Propagation with Backtracking (MPP-BT) was developed[6]. A robust stopping strategy is built by evaluating the evolution of cost increments in backtracking process during the propagation. It can be noticed that only a coarsely user-defined starting point is required for the whole topology extraction. The last curve-like images can be obtained by an additional breakpointconnecting technique.In this paper,we have tried to compare the above mentioned two techniques and inference is made on which is the best technique.

The paper is organized as follows:the first section deals with methods compared in the paper,second section briefs results and discussions followed by conclusion.

II. METHODS

To conduct a comparison study on curve detection algorithms and to infer the best approach in the field.Two papers are taken into consideration

*1.*Detecting curves with unknown endpoints and arbitrary topology using minimal paths

This method is able to detect the same types of contour-like image structures currently extracted by state-of-the-art minimal path techniques, but to be able to do so with far less prior knowledge about both the topology as well as the endpoint locations of the desired curve[2].

*2.*Curve-like structure extraction using minimal path propagation with backtracking

This technique first applies a minimal path propagation from a single starting point and then, at each reached point,backtracks few steps back to the starting point.

III. RESULT AND DISCUSSION

A. Detecting curves with unknown endpoints and arbitrary topology using minimal paths

In this work, they presented a novel minimal path-based algorithm which works on much more general curve topologies with lesser demands on the user for first input compared to earlier minimal path-based algorithms. Almost all prior approaches require precise knowledge of the desired curve's endpoints.

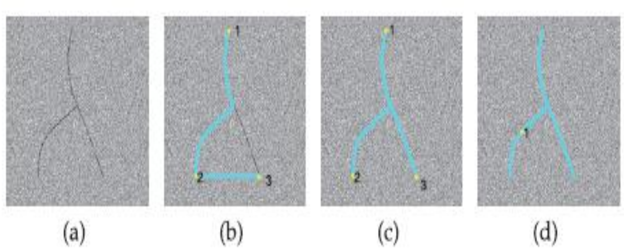

Fig 1. Comparison of results(a) Desired curve. (b) Results from the traditional minimal path.(c) Results from MPWKD. (d) Results from the proposed algorithm.

Fig 1 contains a branched curve to illustrate this goal. The traditional minimal path approach requires prior knowledge of all three endpoints (marked 1, 2, and 3). First, the minimal path between points 1 and 2 is found. Subsequently, the minimal path algorithm is run again between points 2 and 3. The results are not accurate because the minimal path is not able to travel along the elongated desired curve between points 2 and 3, as shown in Fig.1(b). In contrast, the proposed algorithm uses only one arbitrary starting point 1 (does not even have to be an endpoint) to find the complete expected curve shown in Fig.1(d).

A.1.Computation Of Maps U And L:

In the Fast Marching algorithm,first start with the L and U values at the source points in S to be zero and the status of the source points is set to Active. At all other points, U and L values are set to infinity (a very high value) and their status is set to Unvisited. All the Active points are put in a minimum heap data structure according to the value of U. For each Fast Marching iteration, the grid point with the lowest U value, which is called w min , in the minimum heap structure is removed from the heap and its status is changed to Solved Next, the L and U values at the neighbors of the point are updated. This corresponds to 4-neighbors in the 2D case and 6 neighbors in3Dcase. The algorithm stops once all points are labeled Solved.

Auto enhancement method focuses on subjective observation and statistical calculations of mean and variance.

A.2.Robust Algorithm

It is found that for complex topological curves that have sharp corners at branches, the General Curve Detection algorithm terminates before the detection of the complete curve. To fix this problem, introduce an extra condition for algorithm termination. Compute an additional key point r and call it the incremental keypoint. This point r is computed using the Fast Marching procedure with the terminal point q as the source point.

For real life images that have attributes like cracks, ground truth accuracy itself is suspect and it is difficult to accurately quantify the performance of a crack detection algorithm. To overcome this problem, Kaul devised the scaled buffered distance (SBD) metric. The SBD is a scaled version of the buffered Hausdorff distance measure.

B. Curve-Like Structure Extraction Using Minimal Path Propagation With BacktrackingSome Common Mistakes

Minimal path methods are efficient and can avoid local minima by calculating the global energy minima. In this study, they develop a solution termed Minimal Path Propagation with Backtracking (MPP-BT) to tackle the three problems. Here ,the main concept included within "backtracking"can be found in the backtracking algorithms for constraint satisfaction problems in computer science and graph theory, which was proposed as a more better algorithm as compared with the brute force enumeration in searching the solution.But the "backtracking" in the reffered approach goes beyond the basic "tracking backward" operation by fully utilizing the knowledge on visiting preference and cost increments during this backtracking process to give an accurate structure extraction. A robust stopping criterion is built by calculating the evolution of cost increments in backtracking during the propagation.

B.1.MPP-BT approach

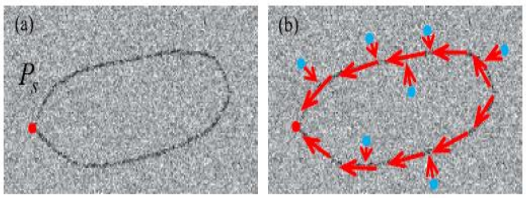

Fig 2. Illustration of the backtracking operation in the minimal path propagation. (a) is the original curve image with the starting point (in red), (b) illustrates that feature points located on red lines get much more visits than non-feature points (the blue ones) in the backtracking path.

As illustrated in Fig.2, if trace back the minimal path from each reached grid point p to the starting point ps ,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). This is due to the fact that feature points always have smaller cost values than non-feature points' and the backtraced 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 information of visiting preference and cost increments in such backtracking process can be exploited to overcome the drawbacks. This algorithm is termed Minimal Path Propagation with Backtracking (MPP-BT).

Also, the shortcut problem and accumulation problem can be solved by a cost resetting scheme based on the cost increments along the backtracking paths. A Stop Propagation criterion was derived by evaluating the evolution of cost accumulation along the back-traced paths. The minimal path propagation is controlled via a stopping strategy limit the propagation within the region around the target features. Note this accumulation is only imposed on the last points other than on all the points in backtracked paths, and this will lead to less computation cost. Also, the shortcut problem and accumulation problem can be solved by a cost resetting scheme based on the cost increments along the backtracking paths.

The "normalized average speed" based stopping strategy is crucial to the performance of the proposed method. Structure missing or wrong inclusion will result if the minimal path propagation stops too early or too late. Proposed stopping strategy is on the overall robust in limiting the propagation within the regions of the target structures. An approach termed MPP-BT 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 accumulation problem that is commonly encountered when using approaches based on minimal path tracking. The backtracking idea is not naive and has already been used to improve minimal path tracking. However, the backtracking process is just aimed at finding the keypoints along the tracking trajectory while it serves to highlight the tracking trajectory by simply adding one count to each backtracked point.

Some non-feature points might also be wrongly connected by such straight counting in backtracking. The three problems can be solved well by the discriminative revisiting and the cost resetting approach along the backtracking paths in the MPP-BT method. To conclude, the proposed backtracking strategy in MPP-BT method includes an effective demand of more information obtained in the backtracking method to overcome the three above problems for the minimal path techniques. In addition, the information obtained during the backtracking method can also be well used for breakpoint connection and for building the stopping criterion to improve the extraction performance.It can often be used in sementation of MRI brain images[7].

IV. CONCLUSIONS

The primary objective of this survey was to compare the curve detection algorithms for shortest path. Almost all prior approaches require precise knowledge of the desired curve's endpoints. They also required desired length of the curve apriori in order to terminate the key point propagation process. The MPP-BT method needs only less user interaction and prior knowledge compared to the prior state-of-the-art minimal path methods, most of which require all desired curve endpoints as initial input for open curves. As compared with the first one MPP-BT method is more efficient since it tackles the accumulation problem in a good way.

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