Crack Detection Thesis Summary

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1. Summary of Thesis

Critical structures like bridges, dams and sewer pipes having cracks are most prominent and earliest indications of the degradation the structure which is essential for the prudent maintenance. Out of serval methods computer vision-based method [1] to automatically identify concrete cracks with minimal involvement from user and cost effective solution. Crack detection in an image is a conventional problem of segmentation where the cracks are extracted as a feature from the image. Image segmentation consists of partitioning an image into homogeneous regions that share some common proprieties. There are two main approaches in image segmentation: edge and region-based. Edge-based segmentation looks for discontinuities in the intensity of an image while as region-based approach looks for uniformity of features color, intensity, structure. There is a statistical method developed for segmenting cracks that are edges from a background in time domain such as Canny edge detection [2], frequency domain [3] and wavelet domain [4, 5, 6, 7].Level set contour based approach [8] can be used for detecting the complex structure of cracks. However, some of these algorithm manipulating temporal information across images with cracks, it is very sensitive to noise, a variation of intensity level, multiple textures, shadows and so, it not reliable and accurate.

The Active Contour Model (ACM) / Snakes [9, 10] are a special form of deformable models and have been being extensively used in image segmentation. ACM is visually represented as closed contours (like an irregular balloon or bubble). It can be modeled based on edge [11, 12, 13], in which basic idea is starting with an initial local placement of contour or curve, to deform the curve to the boundary of the object from the image, under some constraints which often used as an image gradient. These models are typically not only sensitive to noise and weak boundaries but also depends on the placement of initial contour. However, minimal path approach [14] eliminates the dependency of selection of initial curve and demands only two end point (scribble point) of the curve.

Given two user inputted points (p_1, p_2) on the curve by the user, active contour model with minimal path method outputs global minimum curve. In this basic idea to march from one source point to another source point at the cost of minimum energy of the potential function. For crack detection the potential function taken as intensity values at each pixel, because cracks representation in the image is a darker region which is having less intensity value than another background. The resulted curve with minimum energy is referred as a geodesic curve. The solution to this minimization problem is obtained by computation of minimal action map that is geodesic distance map(U). The geodesic map is the minimal energy integrated along the path between point p_1 and any point x. The geodesic map computation is done for all points in an image. Euclidean lengths are computed to the point with for all geodesic distances, which is treated as Euclidean map (L).

Given the source points in an image, to compute geodesic map (U) and Euclidean map (L), out of many method Fast March (FMM) algorithms is selected because of low complexity and it solves the Eikonal equation by taking the up-front derivative. Fast Marching algorithm works on finding out the shortest path as like Dijkstra's algorithm. In the algorithm, U and L are calculated for

4-neighbours. Initially, in the algorithm, all the values in the map U and L are set to be infinite and unvisited while as source points are set to zero and active state. During the course of the algorithm, from any central point propagation of boundary is decided and updated based on minimal orthogonal gradient out of 4-neighbors and the only neighbor which are active or unvisited is updated. Next the status of the each neighbor. After computing the U and L, using back propagation any point pixel in the image found by using gradient decent map U until it arrives at the initial point.

Considering, initial or scribble point is a point on the curve, ratio U/L will decrease until it reaches to the endpoint of the curve. However, it is observed that with this method for finding out the end point fails with images having curves which are easily spreadable from the background with approximately ideal contrast level. So this logic for finding end point detection for finding end point observed to be quite ambitious and in practice, it does not work.

While propagating on the boundary of Fast marching all point have equal geodesic U values and point near the desired feature will have Euclidean distance L. Fast Marching boundary propagates the keypoints are iteratively found out based on condition if the Euclidean distance exceeds the threshold. The threshold value is programmable. And the keypoints is are iteratively identified until the end point is achieved. This method is called as “Minimal Path Method With Keypoint Detection” (MPWKD) approach [15]. It used to the trace out the curve if both end point and one end point length of the curve and in the case of multiple curves with multiple branches the all end point should be known. To remove this dependency by taking the difference of the L value keypoint gradient around the unit neighborhood and L value at keypoint. However, this method needs tuning of the threshold if there is slight variation in image parameters for example contrast of the image.

By selecting an arbitrary point on the curve the first keypoint k1 can find out using MPWKD if that point crosses the Euclidean distance threshold. And it is updated with the new set point or scribble point feature processing for Fast marching algorithm. In this way keypoints from the previous time frame as the initial points for the next time frame, provided already declared keypoint has ignored in next round of processing.

For detecting the end point of a curve which is closed loop, the keypoints is updated with new set E. For any two detected keypoints difference is less than two times threshold value then it is no probability of occurrence of the curve in between these points.

It is observed that these additional points that lead to spurious curve detection have an origin point that has at least 3 neighbors. As and when new keypoint is generated from FMM it is set to 1 and its keypoint is incremented by 1. So if a point on the branch will get incremented by twice it is leading two branches. And this point will have 3 neighbors and we can categorize it as a branch point.

In general, for detecting the curve or counters in the image, the user needs to provide the information about endpoints from the curve or any one of the point and the total length of the curve. Also, there is need of spatial input for images with multiple branches, closes counter or in general any other complex topologies. The Thesis proposes to resolves these problems and proposes the novel method of self-terminating minimal path algorithm based on Fast Marching that can detect crack curves of complex topology (including branches and closed cycles) from a single arbitrary point on the curve (not necessarily an endpoint).

2. Advantages

The Fast Marching Algorithm [16] itself numerically solves the Eikonal Equation as a boundary value problem. The method is performing multiple solutions to measure the shortest time.

If we assume the constant velocity of the waves, this is equal to the shortest distance, so the Euclidean distance is rarely calculated, so only very few square roots are calculated hence it reduces the computation.

3. Disadvantages

a. Disadvantages of FMM and overall algorithm:

If there is a bottleneck in the boundary, then the solution will take a long time, also there will be greater the tortuosity, or complexity of the boundary the longer the solution takes. Also since a PDE is being solved the ratio of the step size to the resolution of any bottle necks or tortuosity will be important.

The endpoint detection by assuming any arbitrary point on the curve is highly sensitive to the threshold value (which is used to decide the keypoints and indirectly used to decide branch points) and tolerance value (which is used to decide the end point). However, these value can be tuned to an optimum value by using novel regression technique by iterating over a large number of samples of images with different dependent parameters.

b. Disadvantages as in all condition not taken care:

The image may have varying lighting conditions, poor contrast, oil stains and shadows and which can act the inherent distraction or noise to the image. Because of this, the overall crack curve may distract from actual shape and size. In this situation the selection of this initial scribble point crack curve would lead to misinterpretation as the accuracy of the overall algorithm depends on how accurately user selects the scribble point on the curve in an image. So there is need to develop preprocessing algorithm so decide and cross verify if it actual crack or noise inherited crack because of extremal factors.

c. Disadvantages as a Semiautomatic model:

The proposed method proposed is semi automatic, where the user needs to compulsory provide scribble point on the curve which represents the crack. If we wish to use this crack algorithm in real time to a system where the image is captured, analyzed by crack detection algorithm and record corresponding location GPS on the Map. However, automatic selection of the scribble point can be implemented, for example, by selecting arbitrary point after global segmentation followed by preprocessing.

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