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REVIEW ON MAINSTREAM METHOD OF SKELETON PRUNING

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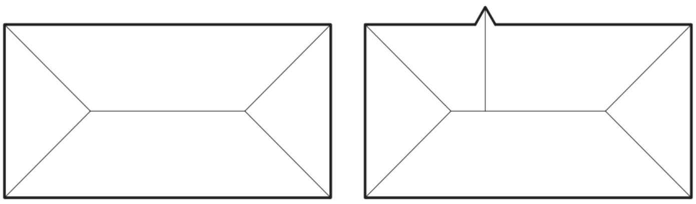
Abstract. The technique of skeleton pruning was generally deployed after the skeletonization of the binary image for filtering unwanted branches caused by the boundary noise, which was a vital pre-processing method before analysis and recognition of the skeleton. It was still a challenging task since there were not standard measurements for distinct the noise branches and original structural branches. In the past decade, there were many approaches based on different perspective have emerged for trying tackle that problem. The review of the most 6 cited paper was conducted in this paper.

Keyword: 2D skeleton, skeleton branch, skeleton pruning.

Introduction

The skeleton, sometimes also named as the medial axis in some literatures, is the result of the skeletonization of the binary image. The foundation of the skeletonization is established by the Blum [1] in 1967. The skeleton is very useful in the field of recognition and object representation because it is a compact abstraction of the visual shape. An ideal skeleton of an object is expected to be have the following properties: it should be a thin subset of the object, consisting of the union of curves; it should be symmetrically placed within the object, it should maintain the same topological (connectivity) [2] as the original shape. However, skeleton has an inherent defect that it is very sensitive to the boundary noise. Slight noise or small perturbations in the boundary could generate redundant skeleton branches that may dramatically influence the topology of the skeleton graph (Fig. 1), which may increase the difficulty of the processing and analyzing of skeletons. Therefore, it is necessary to remove those unwanted branches by using skeleton pruning method.



a *b*

Fig. 1. An example of the instability of skeletons:
a – clean skeleton resulted from normal case;
b – skeleton resulted from the pattern with small perturbations

Mainstream method of skeleton pruning

1. Skeleton Pruning by contour partitioning with DCE.

Bai and his team [6] proposed a skeleton pruning algorithm combining one of the contour partitioning method that is Discrete Curve Evolution (DCE) [3–5]. They proved that the obtained skeletons generated by their method are in accord with human visual perception and stable, even in the presence of significant noise and shape variations, and have the same topology as the original skeletons from the perspective of the theoretical properties and the experiments. The main idea of them is to remove all skeleton points whose generation points all lie on the same contour segment. The generation points are referring to those boundary points that are tangential to the maximal circle of a certain skeleton point. A hierarchical skeleton structure obtained by their approach is illustrated in Fig. 2, where the (red) bounding polygons represent the contours simplified by DCE. Because DCE can reduce the boundary noise without displacing the remaining boundary points, the accuracy of the skeleton position is guaranteed. The continuity, which implies stability in the presence of noise, of their pruning methods follows from the continuity of the DCE.

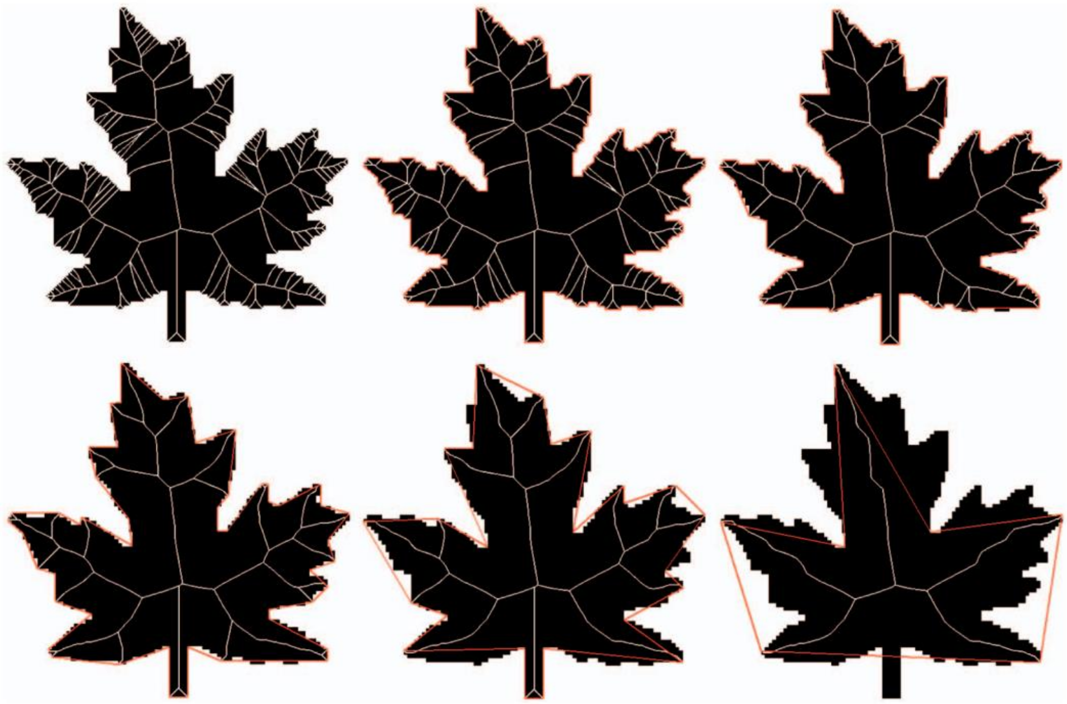


Fig. 2. Hierarchical skeleton of leaf obtained by pruning the input skeleton

The groupwise Medial Axis Transform for fuzzy skeletonization and pruning.

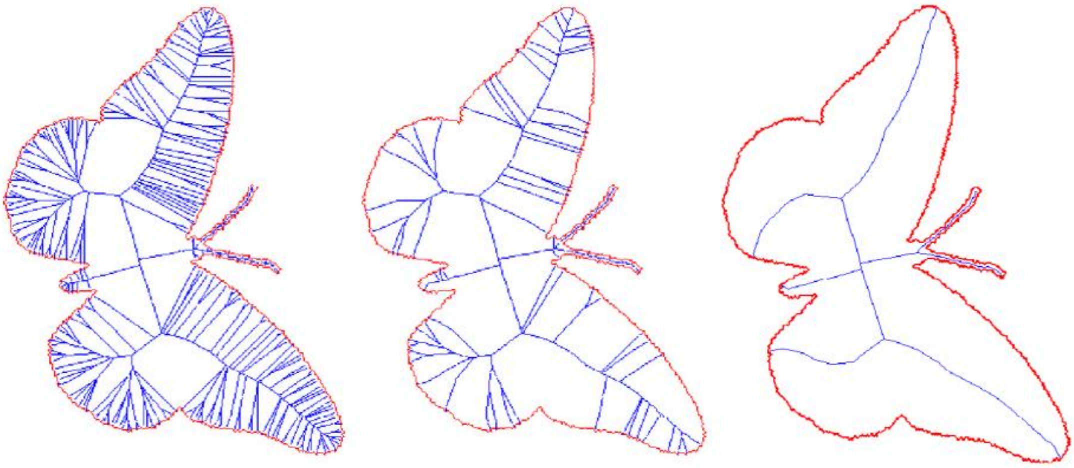
Aaron D. Ward proposed their pruning framework [7] that yields a fuzzy significance measure for each branch, derived from information provided by the group of shapes. They used geometric and topological branch feature information provided by the group as a whole. This groupwise approach represents a third paradigm in computation of branch pruning order. Their approach is more effective in terms of removal of noisy skeleton branches, classification of noisy artificial and real skeletons into different object classes and in producing skeletons that are similar for similar objects.

Skeleton growing and pruning with bending potential ratio.

Pruning skeleton based on bending potential ratio (BPR) is proposed by Wei Shen and his co-workers [8], in which the decision regarding whether a skeletal branch should be pruned or not is based on the context of the boundary segment that corresponds to the branch. The BPR is a measure of the significance of contour segments and depicts the bending potential of a contour segment. Unlike other significance measures that only contain local shape information, the BPR evaluates both local and global shape information. Thus, it is insensitive to local boundary deformation. The skeleton obtained by this method are medially placed, insensitive to boundary noise, multi-scale and provide intuitive ordering of skeleton branches in that negligible skeleton branches are pruned while significant branches remain.

A skeleton pruning algorithm based on information fusion.

HongZhi Liu and his group developed a pruning algorithm [10] based on their previous works [9]. In their opinion, the relative significance of the same branches will be different if see them from different perspectives with different objectives. Different objective measurements have their advantages and limitations. To integrate the advantages of different objective measurements, they consider skeleton pruning as a multi-objective decision-making problem and propose a skeleton pruning algorithm based on information fusion. Additionally, they divided the pruning procedure into coarse-pruning and fine-grain pruning procedure, in which they used combinatorial fusion analysis and the concept of cognitive diversity to fuse various measurements of branch significance including region reconstruction, contour reconstruction and visual contribution. A butterfly example produced by their algorithm is shown in Fig. 3. In general, their algorithm succeeds in avoiding removing any significant branches in advance. not only efficiently delete those redundant branches due to noise, but also be able to generate multi-scale skeletons according with visual judgement



a *b* *c*

Fig. 3. A butterflay example: *a* – is the raw skeleton; *b* – is the skeleton after coarse-pruning; *c* – the result after fine-pruning

A new strategy for skeleton pruning.

Luca Serino [11] has proposed a new skeleton pruning algorithm. They building the skeleton hierarchy and remove the redundant branches by referring the significance measures that take into account the loss in object recovery caused by pruning. The topology of obtained skeleton yield by this method is maintained and the pruning does not dramatically decrease its ability in object recovery.

A skeleton pruning method based on saliency sorting.

To overcome the drawbacks of that the quality of pruning is hard to control because find a suitable threshold is a tough task and of that when the objects of skeletonization vary significantly, it is not necessarily the case that a threshold suitable for most objects even exists, Guo Siyu [12] and his co-workers have proposed a new skeleton pruning algorithm based on saliency sorting. Their method decomposes a skeleton into a number of skeletal components (SCs), and the terminal SCs are removed one by one according to a saliency measure. SCs may be merged into a new one after each removal. The removal process continues until the desirable number of terminals are achieved. Their approach can effectively prune the skeletons from the test image bases, and it has the advantage that the terminal number parameter is very intuitive and easy to set for the applications under concern.

Conclusion

We have reviewed a several popular methods of skeleton pruning. Almost of them are based on the salience measures of the significance of contour segment or skeleton branches to identify the noise branch and then the skeleton pruning can be seemed as the task of seeking a suitable threshold, which procedure need the interaction with the people for tuning. It will be more convenient if there is a skeleton pruning algorithm without any manual pruning. In the future, we will try to develop such an algorithm.

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