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Thinning Algorithms Classification

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Abstract

In this paper we present a general study on five parallel thinning algorithms that preserves topology: [Bernard, Manzanera 1999],[Jang, Chin 1993] [Eckhardt, Maderlechner 1993], [Guo, Hall 1992] and [Hall 1989]. Based on the relation between the medial axis and the obtained homotopic skeleton, we introduce two classification criteria to compare and classify them.

1. Introduction

In literature, several 2D parallel thinning methods can be found, see [1,2,3,4,6]. Proving that such an algorithm always preserve topology is not an easy task, even in 2D. We say that an algorithm preserves topology if obtained skeleton through thinning method has the necessary information to reconstruct the original image. The proofs found in the literature are often combinatorial and cannot be extended to 3D, a fortiori to higher dimensions.

In [5], Couprie presents an intense study on verification methods for the topological soundness of thinning algorithms. He identifies ten algorithms which preserve the topology. Based on this first 'classification' of 2D thinning algorithm, we propose to go further in this study through new quantitative and qualitative criteria. In section 2, we recall final results of Couprie's study. Trough this study we present our classification in section 3. A general discussion concludes this article.

2. Topological thinning algorithms

Couprie [5] present a study of fifteen parallel thinning algorithms, based on the framework of critical kernels. He proves that ten among these fifteen algorithms indeed guarantee topology preservation, and give counter-examples for the five other ones. He also investigates, for some of these algorithms, the relation between the medial axis and the obtained homotopic skeleton. Actually, we will exploit this relationship in our classification next section.

According to the above study, algorithms proposed by T. Pavlidis in 1981 [6,7], by R.T. Chin, H.K. Wan, D.L. Stover and R.D. Iverson in 1987 [3], by C.M. Holt, A. Stewart, M. Clint and R.D. Perrott in 1987 [8],by R.W. Hall in 1989 [4], by Z. Guo and R.W. Hall in 1992 [9] (3 variants), by B.K. Jang and R.T.

Chin in 1993 [10], by U. Eckhardt and G. Maderlechner in 1993 [11], and by T. Bernard and A. Manzanera in 1999 [2] preserve topology.

3. Classification

Let start by presenting two selection criteria based on Jang and Chin's study [12] to make a quantitative evaluation of algorithms. Authors used the ratio between the number of pixels contained in the maximal disks obtained from the skeleton and the effective number of pixels in the original image. This measure, denoted by M_m, is used to determine the proximity of the skeleton from the medial axis.

$$M_m = Area[S']/Area[S] \qquad (1)$$

Area[] is a pixel's counter, *S'* represents the number of pixels contained in the maximal disks obtained from the skeleton and *S* refers to the effective number of pixels in the original image. In our evaluation we used this criterion of skeleton proximity from medial axis with some modification, of (1). Actually, we privilege the ratio between the number of pixels of the skeleton belonging to the axis *Ai* and the total number of pixels of the skeleton *Ni* then the best algorithm will have a C_1 value closest to 1. Thus we can introduce the following criteria:

$$C_1 = Area[Ai]/Area[Ni] \qquad (2)$$

An initial assessment using the three images shown in fig.1, has allowed us to draw first curves (see fig. 2).

Unfortunately this quantitative measure is not sufficient to evaluate algorithms. Actually, even if C_1 tends to 1, the gap between the number of skeleton's pixels belonging to median axis and the number of reference pixels of median axis can be great.

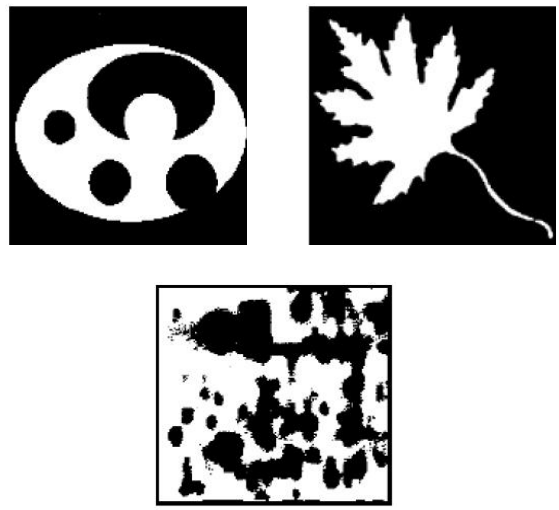

***Fig. 1**: Three shapes for the comparison of thinning algorithms.*

For example, let's consider two algorithms. The first provides 50 skeleton's pixels belonging to median axis, the total number of skeleton's pixels is also 50 and the number of reference pixels is 100. The second algorithm provides respectively 100, 150 and 100.Thus, C_1 for the first algorithm is equal to 1 even if median axis doesn't include many points from the median reference axis; therefore, the deviation is wide: 0.5. For the second algorithm, C_1 is over 1 even if all pixels of the median reference axis are included in reference median axis. To resolve this problem, we propose second criteria C_2. With '*A*' refers to pixels of reference median axis in the following formula:

$$C_2 = Area[Ai]/Area[A] \qquad (3)$$

Through this formula, we can draw new comparison curves between different algorithms (see figure 3).

4. Conclusion

According to figure 2 and 3, the first algorithm proposed by [Pavlidis 1981] has a very good factor C_2 except that it has a bad factor C_1 witch doesn't exceed 0.7. Proposed algorithm by [Chin et al., 1987] has the worst classification according to two criteria so it can be automatically rejected. Although, [Holt et al., 1987] and [Hall, 1989] algorithms have similar factors, Couprie [5] and Jang [10] shows that [Hall 1989] algorithm is an enhanced version of the algorithm [Holt et al., 1987] therefore we chose it to assess.

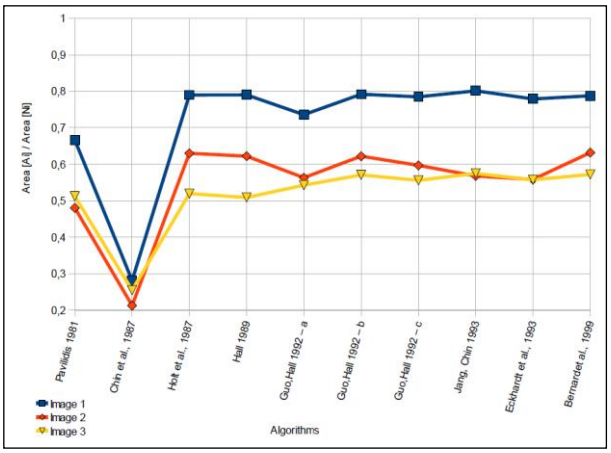

***Fig. 2**: Ratio between the number of skeleton's pixels belonging to the median axis (Ai) and the total number of pixels of the skeleton (Ni)*

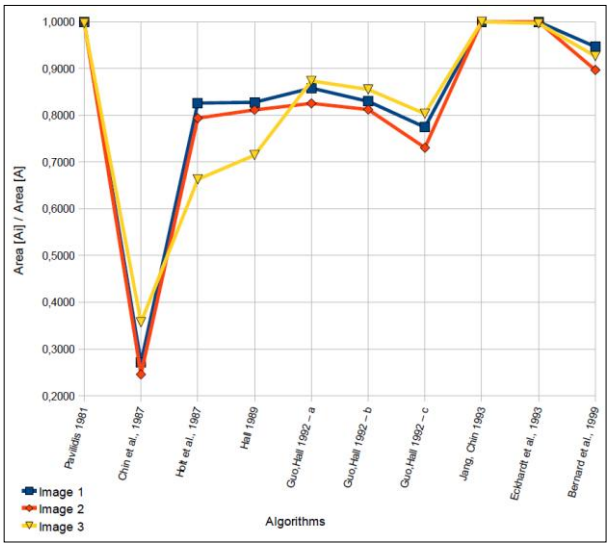

***Fig. 3**: Ratio between the number of skeleton's pixels belonging to the median axis (Ai) and the pixels of reference median axis (A)*

The three versions of [Guo et al.1992] algorithm have similar results but "b" version has a better classification in the two graphs thus this version will be taken as reference. [Jang et al., 1993], [Eckhardt et al., 1993] and [Bernard et al., 1999] have also a very good classification in both graphs and can be kept. Finally we can conclude by the following comparison chart that ranks algorithm by qualitative descending factor:

1	**Bernard, Manzanera 1999**
2	Jang, Chin 1993
3	Eckhardt, Maderlechner 1993
4	Guo, Hall 1992 (b)
5	Hall 1989

Thereafter, we implemented five algorithms to compare their execution time on mono-core machine. In the following obtained results:

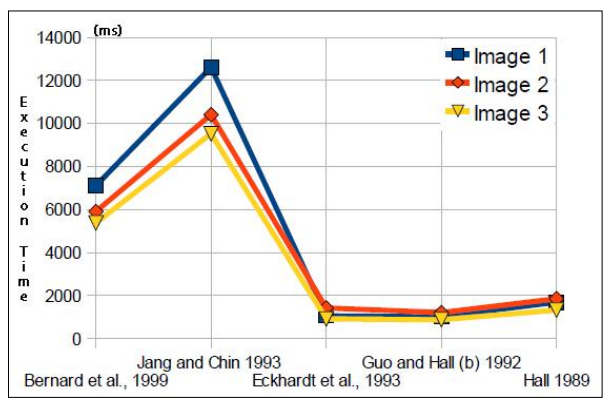

***Fig. 4**: Execution time of serial versions on one core machine.*

This brings us to the following classification according to C1 , C2 and execution time.

1	**Guo, Hall 1992 (b)**
2	Eckhardt, Maderlechner 1993
3	Hall 1989
4	Jang, Chin 1993
5	Bernard, Manzanera 1999

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