TOPOLOGY PRESERVING BINARY CONTOUR SMOOTHING IN 2D IMAGES

IMAGINI 2D DE DETECTIE BINARA A CONTURULUI, CU MENTINEREA TOPOLOGIEI

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Abstract: *Digital topology of images, objects deals with those mathematical characteristics which are not affected by certain deformations. For example stretching and sintering are admissible but shredding is not. Some fields of digital processing of images thinning, sintering, etc. may need the execution of smoother procedures between the steps. Certain noises could appear after some iteration steps which could change and worsen the result of the further processes. These problems are remediable by intercalary contour smoothing operations. If these fill in or reduce the adequate points, then the further sintering method will contribute to the appropriate result.*

Key words: *topology preservation, digital topology, binary smoothing operations, addition, reduction*

INTRODUCTION

A digital picture is represented by the following function f : V → D, where $V \subseteq Z^n$ is the set of points of the picture, and D is a set of gray intensities. In the case of binary picture D={0,1}, which means that the intensity of a point in a binary picture can be only black or white. Black points are called object points, while white points belong to the background and cavities.

As in many application for grayscale pictures, smoothing operators can be applied in binary pictures too. However, binary smoothing operators usually used the morphological operations (i.e., opening, closing, and morphological filtering). These morphological operations in its own does not consider the image topology, but we have to note that some application does not require this property.

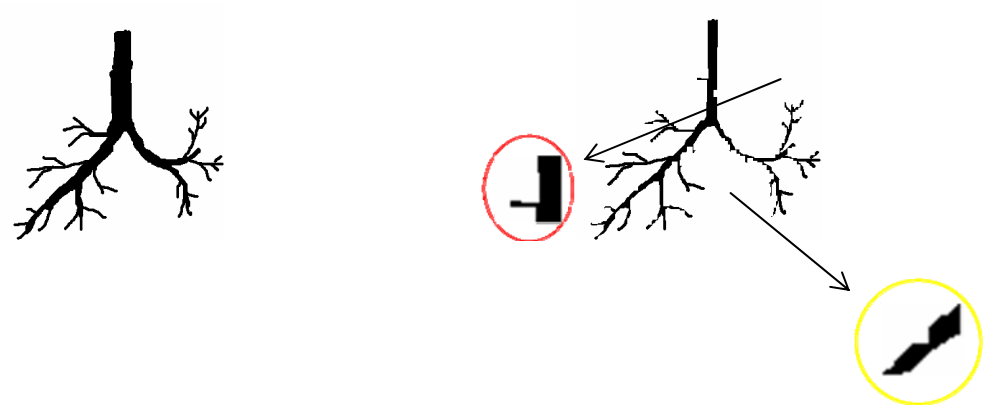


Figure1. mistake between the thinning phases

In this work, we propose a parallel binary smoothing operators, that are topology-preserving.

MATERIAL AND METHODS

What does mean topology preservation?

The digital topology deals with those mathematical properties of binary picture that can not be changed by particular deformations. A deformation does not preserve the image topology if it splits, merges, or completely deletes objects, or creates, eliminates, or merges holes and cavities with the background or each other.

A (4,8) binary digital picture P can be represented by a quadruple (Z^2, 4, 8, B) where Z^2 is a set of object points in orthogonal grid, B □ Z^2 is the set of black points, and its complement is the set of white points. 4-adjacency is assumed to the object points, while 8-adjacency is associated to the white ones. We say that two points p=(px, py) and q=(qx,qy) are 4-adjacent if |px-qx| + |py-qy| <= 1, and 8-adjacent if max(|px-qx|, |py-qy|) <= 1. The black components form the object, finite white components are called cavities, and the background is the only one infinite white component in the picture.



Figure 2. 4-adjacency and 8-adjacency

Addition operator changes a white point to black one, while reduction one changes a white point to black. Reduction operation is often referred to as deletion of point, and we refer the addition operation as filling.

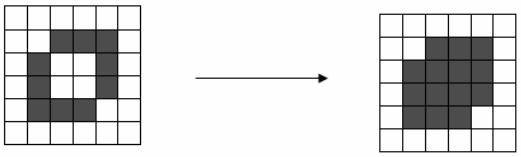


Figure 3. addition

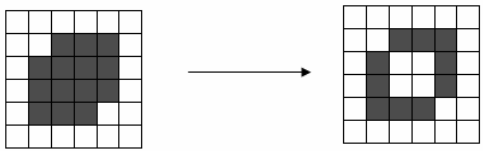


Figure 4. reduction

The conventional morphological operators (erosion, dilation, opening, closing) for smoothing the object boundary do not take the image topology into account, however there exist some contour tracking algorithms for 2D pictures do. Moreover Cuprie and Bertrand [3] proposed a topological smoothing operators based on morphological operators too. Németh, Kardos, and Palágyi also presented a 3-dimensional topology-preserving smoothing operators to reduce the extremities on the object boundary, that can be applied also between two iteration steps of thinnnig processes [4] .
In this work we present a smoothing operator using not just reduction operations but additve ones as well. In order to topology-preservation, we can alter the values the set of simple points. A point is simple if the image topology is not altered by changing its value. The simplicity is a local property that can be decided by examination of the 3x3 environment of a point p. Although changning a value of a simple point does not affect to image topology, removing or filling some simple points simultaneously can be alter the topology.

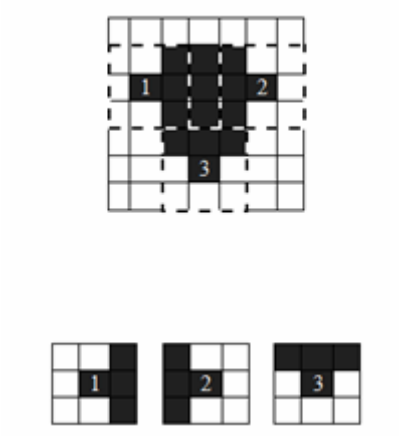


Figure 5. adjusting masks

A parallel operator is topology preserving if it changes values of the elements of a simple sets at a time [2].

In order the topology preservation, our smoothing operators have to fulfil the following requirements:

1. The reduction and addition operators are given by matching templates containing a 3x3 square.
2. The mathcing templates are sorted into groups R1,R2,A1 and A2 that are used in different phases.
3. The reduced or filled point the current phase must form a simple set in the curren image.

The matching templates are sorted into groups such that if any two adjacent point is changed according to the matching templates then the image topology is not altered.

RESULTS AND DISCUSSION

The algorithm is composed of the following phases. [1]

Input: (Z^2, *4, 8, X*) binary image

Output: (Z^2, *4, 8, Y*) binary image

begin

1. Y = X;
2. Y = Y \ {$p \mid p \subseteq Y$ is deleted by set of matching templates R1 reduction masks in (Z^2, *4, 8, Y*)-image};
3. Y = Y \ {$p \mid p \subseteq Y$ is deleted by the set of matching templates R2 reduction masks in (Z^2, *4, 8, Y*)-image};
4. Y = Y $\subseteq$ {$p \mid p \subseteq Z^2/Y$ is filled by set of matching templates A1 addition masks in (Z^2, *4, 8, Y*)-image};
5. Y = Y $\subseteq$ {$p \mid p \subseteq Z^2/Y$ is filled by the set of matching templates A2 addition masks in (Z^2, *4, 8, Y*)-image};

end

It is not hard to see by the concept of minimal non-simple set [2] that the matching templates applying in the same phase can not alter the image topology.

size	***object points***	***del points in 1. phase***	***del points in 2. phase***	***sum delpoints***	***run time (s)***
354x358	20337	248	74	**322**	0.011
377x372	36483	172	45	**217**	0.009
828x841	99119	517	170	**687**	0.036
623x617	71750	231	107	**338**	0.018
488x465	47030	95	45	**140**	0.012
484x474	45982	604	184	**788**	0.027

Figure 6. Product

CONCLUSION

To summary our work, we proposed an binary smoothing operator, that is topology preserving for (4,8) binary pictures, and can eliminate not just additive extremities but subtractive noise as well.
Considering a 3x3 enviroment of a point p, there can be 256 possible configurations. We can compute if a point can be deleted or filled for each configuration and the answer can be stored in a pre-calculated look-up-table (LUT). During the smoothing process, we do not have to check all the matching template for the local configuration but just proper entry in the LUT which takes a unit time [1].

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