MORPHOLOGY IMAGE PRE-PROCESSING FOR THINNING ALGORITHMS

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Abstract

Today, recognition of line characteristic connectivity-preserving objects is an important task in image processing. This paper briefly describes binary morphology and its applications that are important for thinning algorithms. The main purpose of binary morphology in this process is to deal with problem of preventing future errors and irregularities in process of creating skeleton, which is an important step towards recognizing line objects. There are many approaches about image pre-processing that can be used, but this work proposes to use binary morphology because of its versatility and relatively fast execution. In addition it is based on fundamentals that can be used in many other ways including creating skeleton itself.

***Keywords*:** *binary morphology, thinning, skeleton, image processing*

1 INTRODUCTION

Recognition of line objects is complex problem that can be solved in many ways. It consists of more phases depending on approach. Each phase affects next so it is important to obtain good results after the first ones. Pre-processing is the first step in all methods. It modifies input raster to enhanced important information and wipe out those that can cause future problems (like noise). In the next step we usually use some type of thinning [1, 2] to create skeleton. This process is often called skeletonization or medial axis transformation. Skeleton represents original objects by the set of lines that can correctly describe the main features like shape and connectivity. There are many approaches on how to create skeleton with different results [1]. Accuracy of results heavily depends on input quality and characteristics. This paper focuses on the pre-processing phase, which is essential for many image processing tasks including line objects recognition.

2 BINARY MORPHOLOGY

Morphology is a tool for extracting image components that are useful in the representation and description of region shape, such as skeletons, boundaries, or the convex hull. The theoretical foundation of binary mathematical morphology is a set theory. The fundamental operations associated with an object are the standard set operations such as union, intersection, and complement plus translation [3, 4].

Morphological techniques typically probe an image with a small template known as a structuring element (SE). The SE is small compared to the image and its size, zeros and ones in matrix define its shape. The SE is positioned at all possible locations in the image and it is compared with the corresponding neighborhood of pixels. By marking the locations where SE fits or hits the image information about the structure of the image can be obtained. The SE "fits" image if for each of its pixels that is set to 1 (foreground), the corresponding image pixel is also 1. For the 0 (background) pixels in SE corresponding image pixels values are irrelevant. The SE "hits" image if for any of its pixels that is set to 1, the corresponding image pixel is also 1. Image pixels for which the corresponding SE pixel is 0 are also ignored.

3 BINARY OPERATIONS

Morphological operations differ in how they carry out the comparison. Some test whether the structuring element 'fits' within the neighborhood, others test whether it 'hits' or 'intersects' the neighborhood.

Binary Dilation:

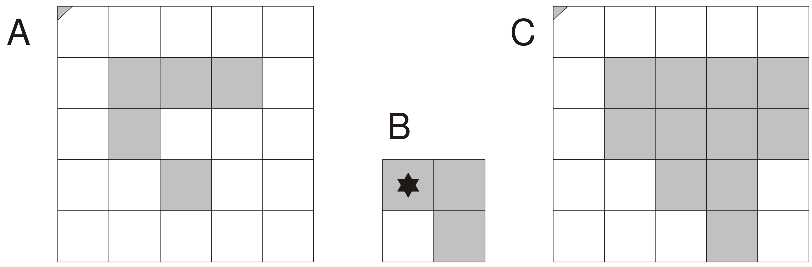

Figure 1 Binary Dilation (A - input picture, B - structuring element (SE), C - result)

$$D(A,B) = \{c \mid c = a + b, a \in A, b \in B\}$$

In this operation SE probes image in all places where image pixels are 1 (gray color in figure 1) and saves all the 1 pixels from SE into the result image.

Binary Erosion

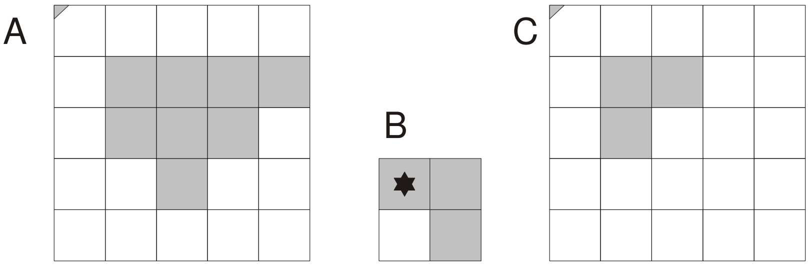

Figure 2 Binary Erosion (A - input picture, B - structuring element (SE), C - result)

$$E(A,B) = \{x \mid x + b \in A, \forall b \in B\}$$

Like in dilation SE probes image in all places where image pixels are set to 1. If SE "fits" corresponding image, center of the SE is saved into the result image.

Binary Opening is combination of erosion followed by dilation:

$$O(A,B) = D(E(A,B),B)$$

Binary Closing is combination of dilation followed by erosion:

$$C(A,B) = E(D(A,B),B)$$

4 MORPHOLOGY APPLICATIONS

Recognition of line objects is a specific process, which deals with two main problems:

1. Connectivity preserving. If two objects are connected in original image, they must be connected also after recognition.

2. Shape preserving. Although it is not important to preserve exact shape or proportions, characteristics of shape should be preserved.

Probably the best way how to deal with these two requirements is to use thinning to create skeleton. In this paper Zhang-Suen thinning algorithm [2] is used to show how input errors and uncertainties influence the skeleton.

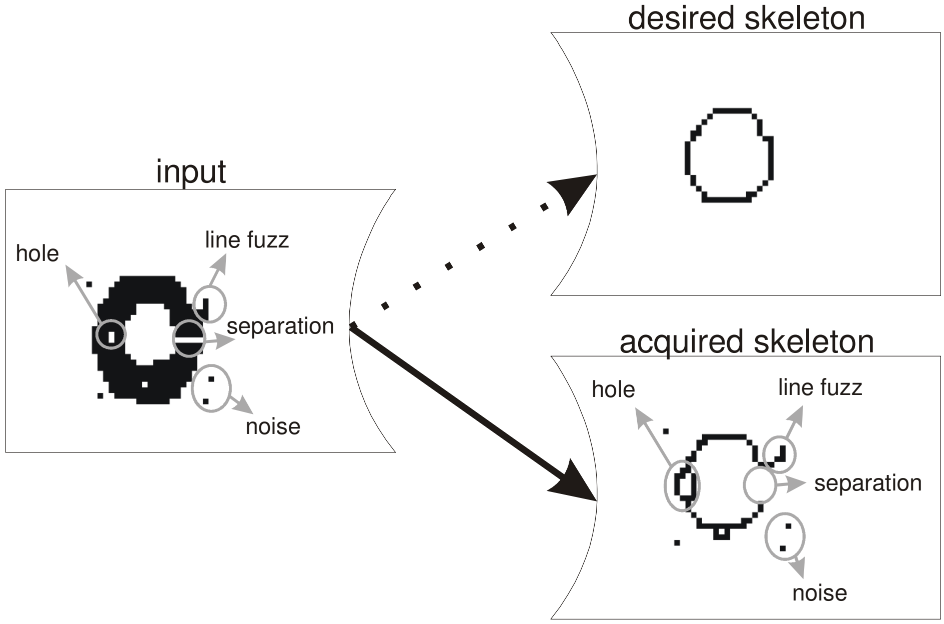

Figure 3 Input, desired skeleton and acquired skeleton (without any pre-processing)

As shown in figure 3, inaccurate input can cause not only bad shape recognition but also what is worse; it can change connectivity of objects. Input picture consists of one object that has shape “O”. The desired skeleton consists of one line object that preserves this shape and also preserves connectivity (it is not connected with other object). On the other hand, skeleton, which was acquired without any pre-processing, consists of more objects that hardly describe original shape and it doesn’t preserve connectivity of its origin at all.

Figure 4 demonstrates possibilities of using binary morphology in pre-processing phase to eliminate most common errors like noise, line fuzz, wholes and separations. Shorts “D” and “E” stands for binary Dilation and Erosion.

Picture A is binary input from which it is possible to get pictures J, G, B and E by using different number and order of dilation and erosion operations. While only one dilation and erosion was used in pictures G and B, pictures J and E show possibilities of using higher number of the same binary operations one after another. If another opening operation is used on picture B, the result on picture C will not change. It’s because operations dilation and erosion are dual and so are the operations opening and closing. The same thing is shown on pictures G and H that were created with the same operation - closing.

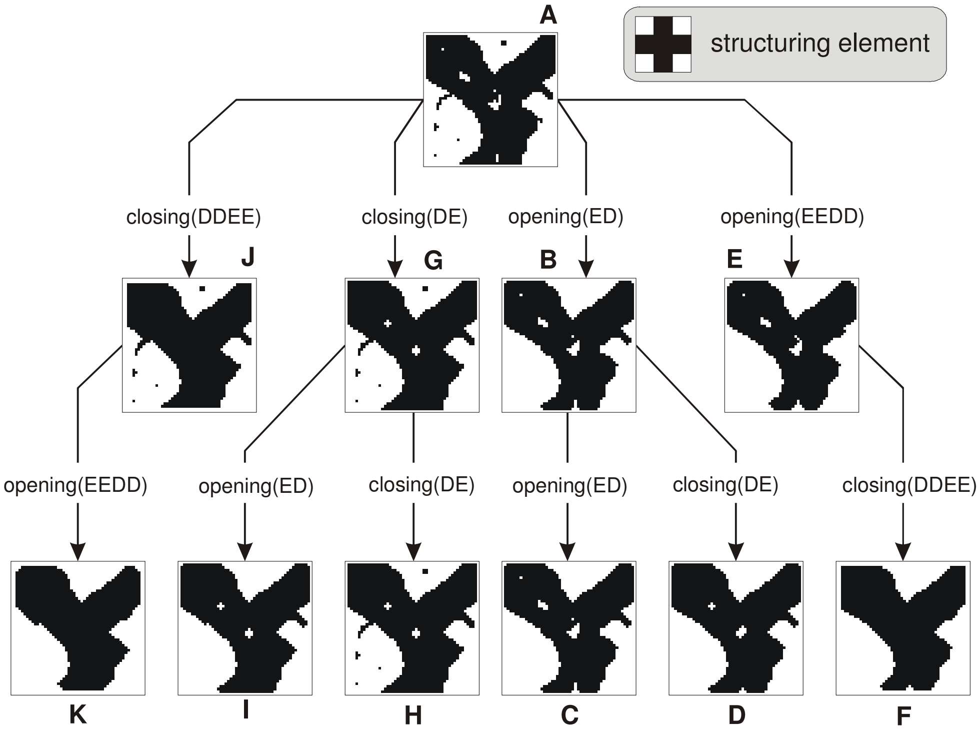

Figure 4 Some possible results of binary morphology

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Binary opening is good for noise reduction and line fuzz removal. Picture B shows that all noise and small line fuzz was removed. Its effect depends on number of iterations (number of dilation and erosion operations) as it is showed in picture E where two iterations were used. If too much iteration is used there's a danger of erasing real parts of the object (line fuzz) or whole objects at all (noise).

Similar situation is shown on pictures G and J, where binary closing is used. This operation causes holes reduction and also can combine separated objects. Like in previous case, its effect depends on a number of iterations. Also there is threat of using too much iteration as it can fill objects that can lead to loss of their line characteristic.

Finally pictures F and K showed that the best way how to use binary morphology is combining binary opening and closing with adequate number of iterations.

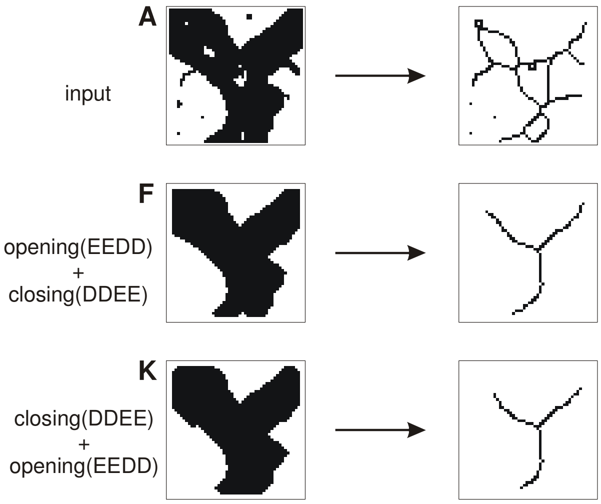

Figure 5 Comparison of thinning results

In figure 5, there is comparison of thinning results obtained by Zhang-Suen algorithm. Original picture A is useless because of many errors (noise, holes, line fuzzes). Pictures (F, K) that were pre-processed by binary morphology produced skeleton that preserves shape and topology.

5 RESULTS AND CONCLUSION

As it was already shown in chapter 4, the most important thing in the binary morphology is to find good combination of binary operations with adequate number of repetition. This is not an easy task and it heavily depends on size of the objects in input and its characteristics.

In figure 6, there are two examples of skeleton, both created from city map shown in figure 7. This map was transformed using threshold [2] into binary image (figure 6A) and then thinned into skeleton without using binary morphology (figure 6B). It is obvious that the result is useless because of huge amount of errors. After pre-processing picture 6A with binary morphology (opening (ED) + closing (DDEE)) into picture 6C most of the errors are removed. Following thinning produces skeleton that preserves all needed characteristics (concerning the input).

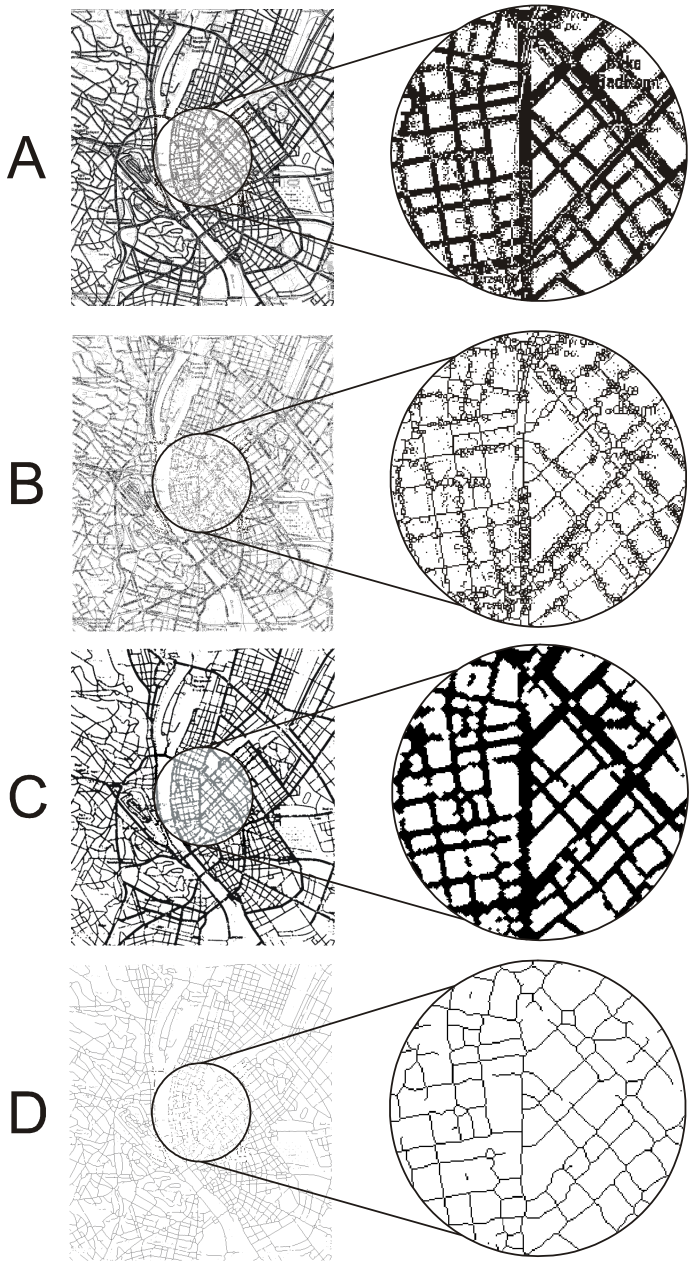

Figure 6 Thinning city map

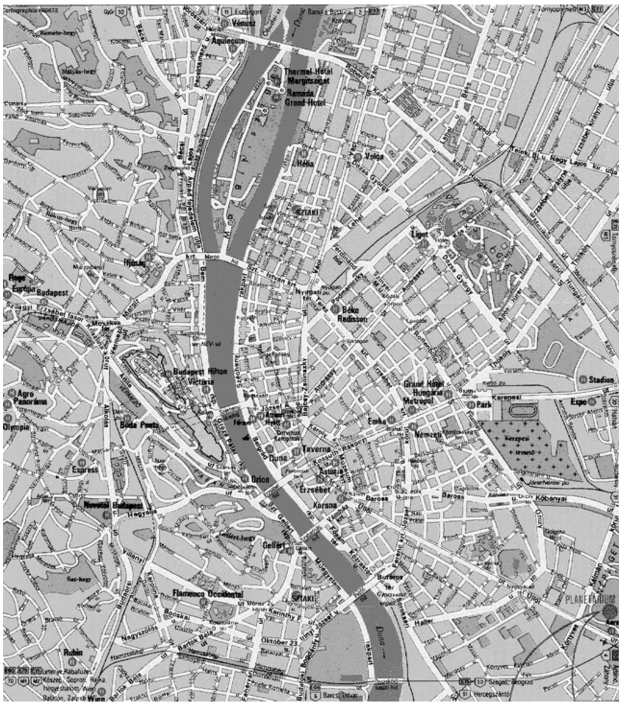

Figure 7 City map

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