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Morphological Enhancement of Medical Images

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Abstract: Simulation methods in medicine play the important role in recognition of dangerous diseases like cancer. Medical images of tissues and cells may contain information that is often hidden to the doctor's eyes. Some details like pathological changes are hardly visible without a special image enhancement. This paper shows an effective application of special types of morphological filters that were able successfully enhance grayscale or color medical images of tissues and cells.

Key Words: Medical images, enhancement, mathematical morphology, simulation.

1 Introduction

Simulation methods of growing cancer or other pathological changes in tissues are important tasks in the analysis of medical images. There is a growing need for simulation methods and analytical processing as well. Medical images of tissues and cells may contain information that can be hidden to the doctor's eyes. Some details like pathological changes are hardly visible without a special image enhancement. In order to perform the simulation properly and to analyze the disease in the early stage a special enhancement based on grayscale mathematical morphology was applied. Mathematical morphology is based on a set theory and it is used to analyze geometric shapes of objects. The most common is binary morphology described for example in [1, 2, 3]. Unfortunately, the binary morphology is limited to the binary (black and white) images, and tasks like finding boundaries of an object or a morphological thinning.

Simulations using grayscale morphology are not as widespread as when using binary morphology. Morphological operations can be extended to functions [2] that operate on non-binary data like grayscale or color images. This paper shows an effective application of such morphological filters and special types of morphological gradients suitable to enhance grayscale or color images.

2 Theory

2.1 Binary Morphology

Binary morphology is well known and it is described in [1, 2]. Morphological operations are based on a set theory. A smaller set B called structure element is applied on a larger set A - an image. Basic operations are the erosion and dilation, see Fig. 1. The erosion is a set of points x to which the structure element B may be translated while remaining entirely within the original set A (an intersection of set translations - Minkowski set subtraction): $A \Theta B = \{x : (B)_x \subseteq A\} = \bigcap_B A_x$. The dilation is the set of points to which B may be translated and still intersect A with at least one point (a union of set translations - Minkowski set

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** Department of Geoinformatics, Palacky University, Tr. Svobody 26, CZ-779 00 Olomouc addition): $A \oplus B = \{x : (B)_x \cap A \neq \emptyset\}$. The structure element B is reflected about the origin when dilation is performed. A reflection is omitted when a symmetric structure element is used.

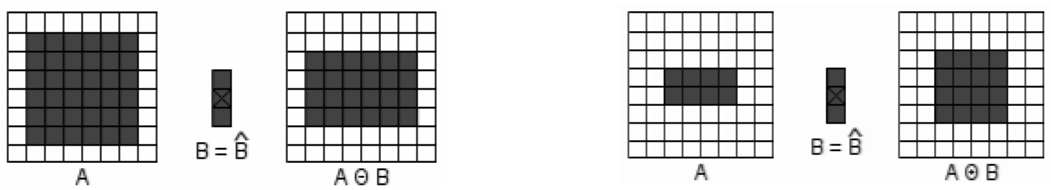


Fig.1 – a) Morphological erosion b) Morphological erosion

Compound morphological operations are opening and closing. Opening is the operation of erosion followed by dilation $A \circ B = (A \Theta B) \oplus B$. Closing is the operation of dilation followed by erosion $A \bullet B = (A \oplus B) \Theta B$. Binary morphological operations are not applicable to grayscale images. In order to be applicable to grayscale images the extension described in the following paragraph is needed.

2.2 Grayscale Morphology

Grayscale morphology is not as widespread as binary morphology. The image is considered to be a function *a(j,k)* that represents the intensity level, and the structure element is expressed as a function *b(j,k),* $j,k \in Z^2$. Let D_a, D_b be the areas where the functions $a(j,k)$ and $b(j,k)$ are defined, i.e. the area of the image and the area of the structure element respectively. The grayscale erosion is then defined [2] as:

$A \Theta_G B = (a \Theta b)(m,n) = \min\{a(m+j, n+k) - b(j,k)\}$ where $(m+j, n+k) \in D_a, (j,k) \in D_b$.

Similarly grayscale dilation is defined as:

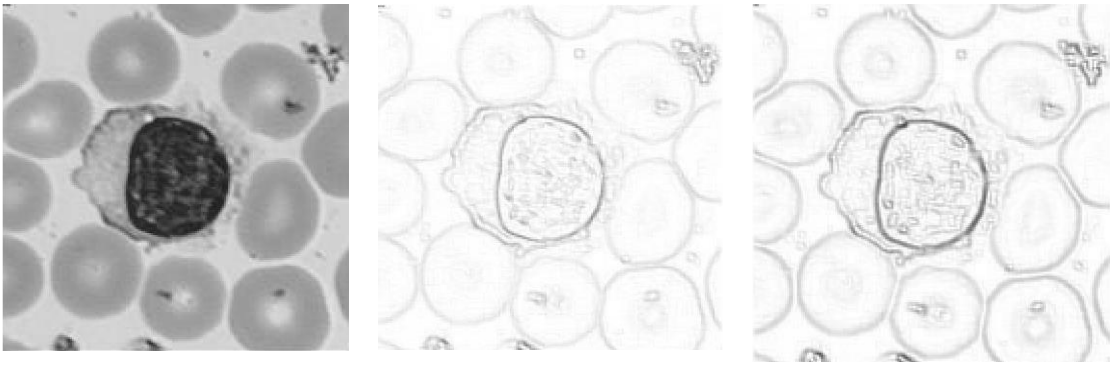
$A \oplus_G B = (a \oplus b)(m,n) = \max\{a(m-j, n-k) + b(j,k)\}$ where $(m-j, n-k) \in D_a, (j,k) \in D_b$.

It is often important to stress properly the edges of the cells in medical images so that a doctor can properly analyze pathological changes. The basic grayscale morphological gradient defined as $GRD(A) = (A \oplus_G B) - (A \Theta_G B)$ or inner gradient defined as $GRD^-(A) = (A - (A \Theta_G B))$ did not give satisfactory results. Therefore we tried and implemented other types of morphological gradients to stress and respect the structure of the cells in the image. Grayscale opening $(A \circ_G B)$ and closing $(A \bullet_G B)$ is defined similarly as it is in binary morphology.

3 The Application of Morphological Filtering and Results

The images of tissues have some kind of regular but usually not clearly visible structure. The aim is to find and stress the structure (or texture). The difference of closing and opening $TEX = (A \bullet_G B) - (A \circ_G B)$ gives information about the texture of the image.

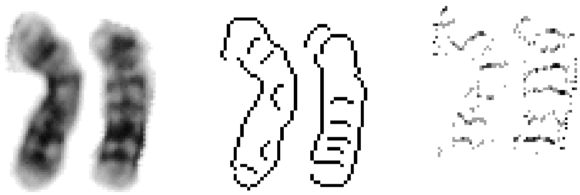
The enhancement of gradually and slowly changing edges can be achieved if the difference of closing and opening was subtracted from the basic gradient: $G_{G-(TEX)} = GRD - ((A \bullet_G B) - (A \circ_G B))$. This technique gives better results on the smooth and gradually rising haemal cell edges; compare the difference in Fig 2. The results of “visibility improvement” were judged by a doctor. The tests were done on a database of 30 images. The improvements of images were marked as very good in 21 cases, and as good in 9 cases.



a) b) c)

Fig.2 Haemal cells: a) Original image, b) Standard gradient, c) Subtraction of the difference of closing and opening from the gradient.

Other problem that is currently solved is how to enhance chromosomes so that they can be compared with the given pattern. One of a successful application of morphology is the enhancement of images of chromosomes. When looking for the appropriate striping of chromosomes, techniques like directional filtering followed by Canny's edge detection gave misleading results Fig 3. White Top-Hat transform can be defined as $WTH(A) = (A - (A \circ_G B))$ or Black Top-Hat transform as $BTH(A) = ((A \bullet_G B) - A)$. We achieved satisfactory results by a modification of Black Top-Hat transform $BTH(A) = ((A \bullet_G B) - A) \cdot w$ (were w is a multiplication factor to stress the difference) with the appropriate structuring element used to emphasize the dark striping. The appropriate stripes on chromosomes were found on non-uniform light background. Correct features were extracted immediately with BTH. Compare the result of with Canny edge detection that did not detected the appropriate striping without a special filtering, see Fig 3.



a) b) c)

Fig 3. Chromosome filtering: a) Original image, b) Misleading results achieved by directional filtering and Canny edge detection, c) Appropriate striping achieved by modified BTH.

4 Conclusions

Properly designed morphological filters are suitable for the enhancement of medical images. Using usual gradient filters can cause the appearance of undesired features in medical images. Cell structures and edges can be enhanced effectively by using appropriate type of morphological gradient filters. These types of gradients are more suitable for processing some types of medical images. Correct features from chromosomes were extracted with modified BTH and appropriate structure element rather than by filtering the image followed by Canny edge detection. Our contribution is the design and implementation of special types of morphological filters. These types of filters were more suitable for processing some types of medical images. The implementation is done completely in Java so it can be easily accessible via web by different web browsers.

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