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# Algorithms applied to segmentation and computation grandular ducts in microscope colon image

***Abstract.*** *The paper presents the methods of the microscope colon image processing for segmentation and computation of numerical features of grandular ducts. In the first part we describe the grandular ducts segmentation algorithms applying the morphological functions. The second part contains the description of the techniques of the grandular ducts features computation algorithm The paper describes shortly the main morphological functions, the numerical characterization of the grandular ducts and the segmentation and computation algorithms. The work contains also medical introduction, problem explanation and description of the main goals. The results of the numerical experiments will be also presented and discussed.*

***Streszczenie.*** *Praca poświęcona jest opracowaniu metod przetwarzania obrazu wycinka jelita grubego dla potrzeb wspomagania diagnozy lekarskiej w chorobach Leśniowskiego-Crohna. Praca prezentuje proces wyodrębniania i liczenia cech numerycznych cew gruczołowych. W pierwszej części opisujemy algorytm segmentacji cew gruczołowych z zastosowanie funkcji morfologicznych. Część druga zawiera opis technik liczenia cech numerycznych. W pracy opisany został także zaproponowany algorytm służący do mierzenia odległośći między cewami. Praca opisuje opis numeryczny cew, algorytmy segementacji i pomiaru odległości. W pracy znalazło się również krótkie wprowadzenie medyczne, wyjaśnienie problemu i opis głównych celów, które staralismy się osiągnąć. Wyniki jakie uzyskaliśmy zostały opisane i przeanalizowane.*

**Keywords:** digital image processing, morphological operations, medical diagnosis of Leśniowsi-Crohn disease
**Słowa kluczowe:** cyfrowe przetwarzanie obrazów, operacje morfologiczne, choroba Leśniowskiego-Crohna

## Introduction

Inflammatory Bowel Diseases belong to the group of chronic, incurable diseases of gastrointestinal tract. They are characterized by the spontaneous remissions and relapses of their etiology not unexplained up to now. To this Inflammatory Bowel Diseases we may include on one hand the *Colitis Ulcerosa* and Lesniowski-Crohn disease, and on the other one the microscope colitis (collagenous colitis) and also some non-specific inflammations. When grandular ducts are attacked by the human defense system it is the important fact to diagnose that the disease begins. In the microscope colon image we can see humans defense cells which are attacking grandular ducts and the grandular ducts destroyed by them. The response to the attack is appearance liquid in the stoma of tissue, area between granular ducts extends and the granular ducts begins dividing..

The paper will be concerned with the segmentation, recognition and characterization by the numerical features of the granular ducts on the basis of the microscope colon image. The most important stages of this task include: filtration and segmentation of the image, extraction of the individual granular ducts, generation of numerical features for each granular duct and as a final stage computation distances and spaces between each one. As a result of such complex process we can certify the intensity of the inflammation, which is very important factor in medical diagnosis. The main goal of this work is to estimate numerical features of the grandular ducts and between them. It may discover that there are associations between each disease and numerical features. This work may also help the doctors to diagnose if the disease started and if yes, which sort.

## The problem description

The input data in our experiment is a microscopic digitized colon image. It is the image of the biopsy of the tissue of the magnification equal 10. The image is saved as the bitmap file for further processing. The typical image of this kind is depicted in Fig. 1.The large, dark part of the image is in our interest. They represent the grandular ducts and should be segmented. All cells (represented by small dark objects) should be removed. Our main concerns are the oval, dark objects which are granular ducts.

The first step of processing is the extraction of the granular ducts trough segmentation and elimination of the others elements. We achieve it using the morphological operations. After segmentation each granular duct represents the individual image which must be preprocessed in order to be characterized by the numerical features. These features are geometrical features. The very important is to measure the distances between the nearest granular ducts. As a result we get each granular duct associated with the numerical features and the nearest one.

Fig.1. The typical microscope colon image

The main steps of the problem solution may be summarized as following:

- extraction of the individual grandular ducts from the microscopic colon image
- generation of the geometrical features well characterizing if inflammation starts or not
- computation the distances between the nearest grandular ducts
- saving all the results to data base

After computation of all distances and geometrical features we will estimate if any of the numerical features is associated with disease. The results given by this automatic system are also used by the medical doctor to assess the intensity of inflammation and the advancement of the illness in the human organism.

**Segmentation algorithm**

The introductory step of the colon image processing is the extraction of the grandular ducts from the image. We have done it by applying the filtering and segmentation processes. The applied algorithm consists of the following stages.

- Reading the input bitmap image. It is saved in the matrix form $\mathbf{I}(x, y, 3)$, in which x and y are the coordinates in horizontal and vertical axes, while 3 is the number of the intensity levels of red, green and blue color component.
- Contrast adjustment:
  - ✓ The background is transformed to white color
  - ✓ The other objects are transformed to dark colors
- Transformation to the binary image
- Removing the smallest elements:
  - ✓ Implementation of the morphological operation of opening. We have used the structural element in the form of a disk of the size equal 3.
  - ✓ Morphological operation of closing by the structural element in the form of a disk of a size equal 7.
  - ✓ Morphological operation of filling the holes. The largest objects which are represented by grandular ducts are empty and after this operation we obtain filled elements.
  - ✓ Using dilation with structural elements of size equal 20.
  - ✓ Morphological closing.
  - ✓ Morphological operation of reconstruction. The marker we can see in the figure 2 and the mask in the figure 3.

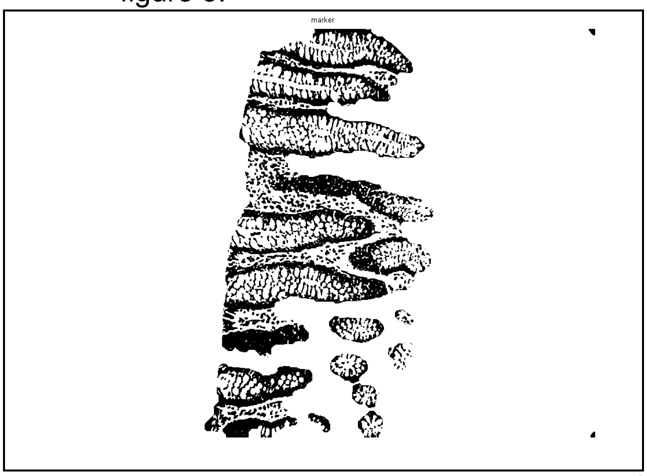


Fig.2 The marker used to the morphological operation of reconstruction

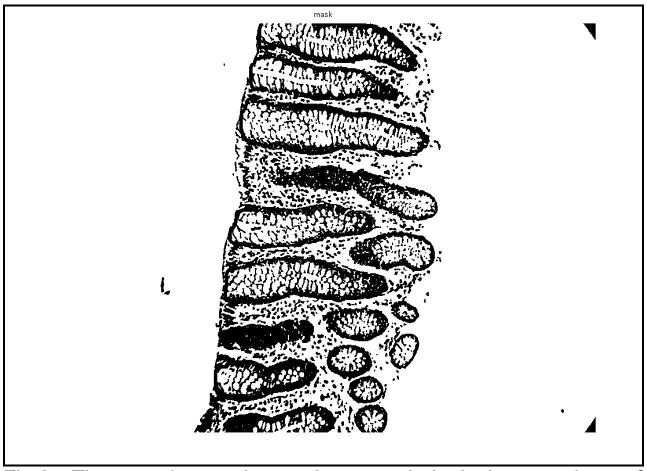


Fig.2 The mask used to the morphological operation of reconstruction

- ✓ Morphological closing by structural element of the size equal 5
- ✓ Filling the holes
- ✓ Opening, closing, filling the holes, closing

- The smaller objects than 5000 pixels are eliminated
- At the end we obtain the ready, processed image with segmented grandular ducts and removed small objects . The figure 4 presented processed image.

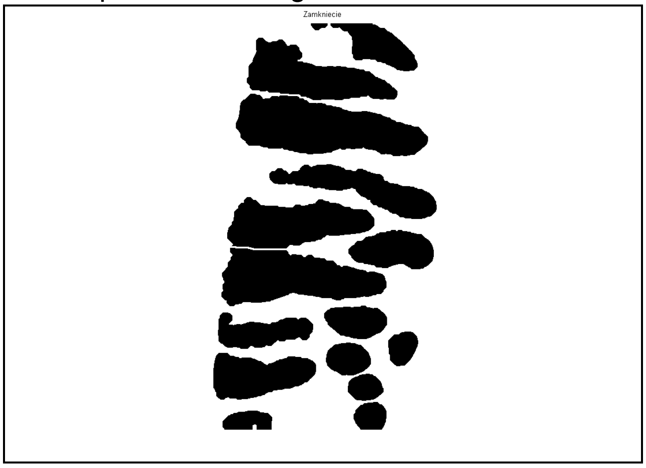


Fig.4 The ready, processed image. The black objects we can see are grandular ducts.

Sometimes we must manually cut area between bad segmented grandular ducts. This results from big differentiation between images – from dark to light or from full objects images to a few objects. It is very difficult to find an universal algorithm to extract all the grandular ducts from images of any sort.

After we have got processed image we may start to compute the numerical features and distances between the segmented grandular ducts.

**The computation of the numerical features**

The grandular ducts are described by the follows numerical features:

- Area – real area of the grandular ducts (in pixels)
- Radius – short radius and long radius. As the grandular ducts have ellipsoidal shape we may compute short and long radius. To do this we propose the algorithm:
  - ✓ We may compute the long radius by finding two the most distant pixels belonging to grandular duct. The long radius of the grandular duct is in the figure 5.

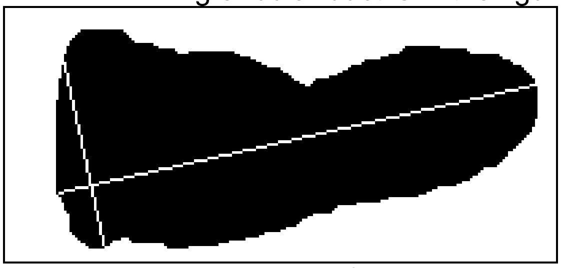

Fig. 5 The long and short radius of the grandular duct

- The small radius is found by the finding the longest, perpendicular line to the long radius
- Factor of circularity – ratio of short radius to long radius:

$$F_C = \frac{L_{sr}}{L_{lr}} \quad (1)$$

Where: Lsr – short radius, Llr – long radius

- Real perimeter (in pixels)
- Convex perimeter
- Convex area

Table I
The numerical features of the grandular ducts

| G. d | Short radius | Long radius | Area | Fc | Perim | C. Perim | C Area |
|---|---|---|---|---|---|---|---|
| 1 | 186 | 357 | 49563 | 0.5233 | 811 | 622 | 50255 |
| 2 | 264 | 418 | 65710 | 0.6317 | 1009 | 919 | 66804 |
| 3 | 199 | 419 | 59490 | 0.4749 | 924 | 778 | 61164 |
| 4 | 192 | 278 | 38654 | 0.6915 | 675 | 478 | 38792 |
| 5 | 425 | 195 | 64222 | 0.4592 | 905 | 670 | 64516 |

When the grandular ducts are segmented and the numerical features are computed we may start to compute the distances between the grandular ducts. The distances are very important for doctors to diagnose if inflammation begins and what sort of inflammation is.

**The computation of the distances between the grandular ducts**

To compute the distances between the grandular ducts we developed the following algorithm:

- First step is to find the long radius of each grandular duct. It is important information about orientation in the image.
- Next every 5 pixels we must find the perpendicular line to the long radius.
- If the perpendicular line intersects the long radius of the other grandular duct the distance between them will be saved
- Then the mean distance between each neighbor duct is computed. Standard deviation is also computed to estimate the accuracy of the computation
- The distance computed from the nearest ducts is only saved
- All the results is saved in database

The figure 6 presents the method of the distances computation.

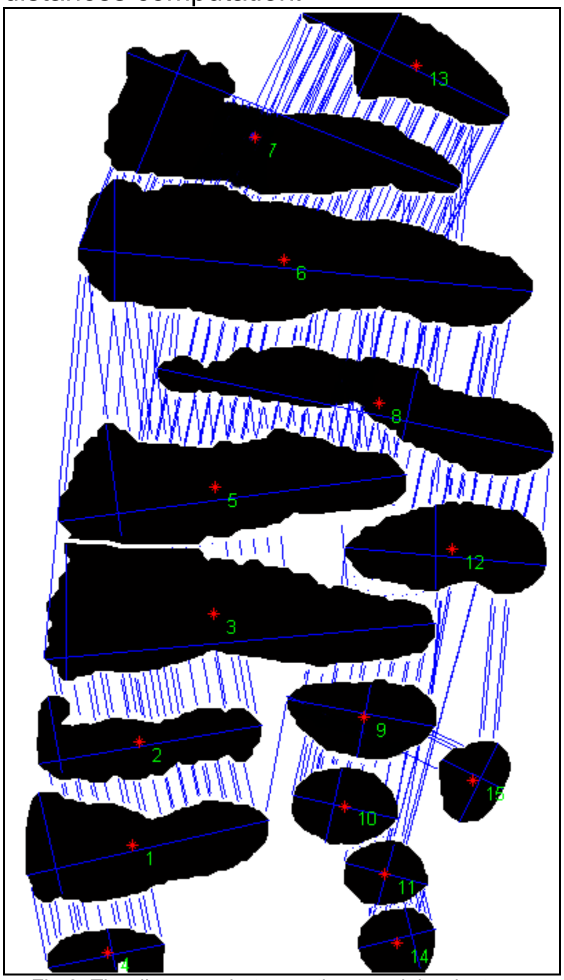


Fig.6 The distances between the grandular ducts

The distances between the grandular ducts are visible in the figure 6 as the lines between them. The lines on the ducts represents short and long radiuses. All the distances are presented in table 2.

**The results of numerical experiment**

The numerical experiments of grandular ducts segmentation have been performed on the data base of microscopic colon images acquired in the Institute of Pathomorphology, Warsaw Military Hospital. We have used the images of tissues of the magnification equal 100. We have used 193 images to the experiment, which is equal to the same number of patients. The results are saved in the database. The example of the result from the image are presented in the tables 1 and 2.

It is very difficult to estimate the numerical error of the results. There are no information about the features which we compute. The standard deviation of the distance is used to estimate if the result is correct. We may visually estimate if the segmentation is correct.

The paper has presented the automatic method of the grandular ducts segmentation and the numerical features computation. The results are only the first step in the correlation research between the disease and the numerical features computed in this experiment. The doctor must find the correlation and then the system will be helpfully in diagnostic requirements

Table II
The distances between the grandular ducts

| G.d | Neighbour | Distance | Std |
|---|---|---|---|
| 1 | 2 | 10 | 3 |
| 2 | 1 | 10 | 3 |
| 3 | 9 | 5 | 4 |
| 4 | 1 | 12 | 10 |
| 5 | 12 | 5 | 2 |
| 6 | 7 | 23 | 22 |
| 7 | 6 | 23 | 22 |
| 8 | 12 | 23 | 11 |
| 9 | 3 | 5 | 4 |
| 10 | 11 | 8 | 2 |
| 11 | 10 | 8 | 2 |
| 12 | 5 | 5 | 2 |
| 13 | 7 | 37 | 20 |
| 14 | 11 | 9 | 7 |
| 15 | 9 | 23 | 51 |
| 16 | 24 | 8 | 2 |

REFERENCES

[1] P. Soille, *Morphological Image Analysis*, Principles and applications, Springer, 2003

[2] Zygmunt Wróbel, Robert Koprowski, *Praktyka przetwarzania obrazów w programie Matlab*

[3] Ryszard Tadeusiewicz, *Przemysław Korohoda Komputerowa analiza i przetwarzanie obrazów*

[4] K.W.Zieliński, *Wstęp do morfometrii i patologii ilościowej*

[5] Matlab user manual – *Image processing toolbox*, MathWorks, Natick, 1999

[6] Gonzalez, R.C. and R.E. Woods, *Digital Image Processing*. 1992, Reading, Massachusetts: Addison-Wesley.

[7] Heijmans, H.J.A.M., *Morphological Image Operators. Advances in Electronics and Electron Physics*. 1994, Boston: Academic Press.

[8] Young, I.T., *Quantitative Microscopy*. IEEE Engineering in Medicine and Biology, 1996.

[9] Kulpa, Z., *Area and perimeter measurement of blobs in discrete binarypictures.* Computer Vision, Graphics and Image Processing, 1977.



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