ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889,
2024-6.875 ResearchBib IF: 8.848 / 2024

THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME-4, ISSUE-4

DIGITAL IMAGE SEGMENTATION PROCEDURE AS AN EXAMPLE OF AN NP-PROBLEM

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ABSTRACT:

Digital images are a source of additional information about the world around us. Such a source plays an important role in the process of medical diagnosis and research into human health. Digital imaging allows you to obtain the necessary information remotely without additional interference in human life. This can be done using various digital image processing and analysis techniques. However, these methods are typically an NP-problem. The paper discusses the procedure for segmenting medical digital images. The criteria are shown to achieve the required solution when segmenting an image as an NP-problem.

Key words: Segmentation, Perception, Analysis, NP-problem, Quality, Metric, Digital image.

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ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889,
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Raqamli tasvirlar atrofimizdagi dunyo haqida qo'shimcha ma'lumot manbai hisoblanadi. Bunday manba tibbiy diagnostika va inson salomatligini o'rganish jarayonida muhim rol o'ynaydi. Raqamli tasvir inson hayotiga qo'shimcha aralashmasdan kerakli ma'lumotlarni masofadan turib olish imkonini beradi. Bu turli xil raqamli tasvirlarni qayta ishlash va tahlil qilish usullari yordamida amalga oshirilishi mumkin. Biroq, bu usullar odatda NP muammosidir. Maqolada tibbiy raqamli tasvirlarni segmentlash tartibi muhokama qilinadi. Tasvirni NP-muammo sifatida segmentlashda kerakli yechimga erishish uchun mezonlar ko'rsatilgan.

Kalit so'zlar: Segmentatsiya, Idrok, Tahlil, NP-muammo, Sifat, Metrik, Raqamli tasvir.

INTRODUCTION

The study and analysis of digital images is one of the current areas of modern research [1]-[3]. Such a source of information allows you to study a certain phenomenon remotely, without any outside interference disrupting its natural process. Such work is especially relevant in various medical studies. They help to understand those processes that occur at the microscopic level and cannot be perceived by the ordinary human eye.

Solving such medical problems helps to diagnose early detection of diseases or analyze the patient's condition. It is also possible to study various diseases or monitor their progress and the effectiveness of patient treatment. Various types of images can be used here depending on the context of the task [4]-[10]. Digital medical images occupy a special place among such data [11]-[19].

To analyze digital images, various methods and approaches are used, both classical [20]-[25], and those that contribute to solving the problem and are non-standard, setting possible directions for research [26]-[33]. At the same time, special analysis methods can be distinguished here, such as: removing noise, increasing image contrast, highlighting object contours, segmentation, recognition. The solution to most of these problems should be considered NP-problems. Here we highlight the image segmentation task, which may include several separate subtasks. This, ultimately, determines the significance of this work, its theoretical and practical significance.

Thus, the main goal of the study is to consider the problem of image segmentation and generalize estimates of the effectiveness of its solution as an NP-problem.

Related work

Image segmentation is one of the areas of research in digital medical image processing. At the same time, it is also worth highlighting those studies where segmentation is considered as an NP-problem. The need for such consideration for medical images is determined, first of all, by the importance of decision-making in this aspect.

The study by D. D. Patil and S. G. Deore is devoted to the analysis of segmentation methods that are used for the analysis of medical images [34]. The authors emphasize that segmentation is an important and complex process of image analysis, which can consist of several stages. In this case, during the segmentation process, a certain structure in the image must first of all be outlined and highlighted so that it can be considered [34]. For these purposes, methods for identifying the boundaries of objects, which are an integral part of segmentation, can be used.

The work [35] also discusses and summarizes various issues of using medical image segmentation algorithms. In particular, the paper provides an overview of medical image segmentation and statistical mechanics methods based on a new method called lattice Boltzmann

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889,
2024-6.875 ResearchBib IF: 8.848 / 2024

method (LBM) [35]. The authors also review medical image segmentation methods based on thresholding, region-based, clustering, and edge detection [35]. This also confirms the multi-stage and diverse nature of segmentation. One such step is detecting the edges of objects. The paper also notes the complexity of medical image segmentation and emphasizes that various algorithms do not completely solve the segmentation problem. This confirms the importance of considering segmentation as an NP-problem.

M. A. M. Salem, A. Atef, A. Salah, and M. Shams explore various methods for medical image segmentation [36]. The work identifies three groups of such methods. It is also noted that a digital image can be viewed as a function of two or three spatial dimensions in the case of color images. This expands and complicates the overall image processing and segmentation procedure.

J. Kleinberg, C. Papadimitriou, and P. Raghavan identify and analyze various image segmentation problems [37]. In this case, special attention is paid to the problem of optimizing the image segmentation procedure. The authors also point out that this procedure belongs to the class of NP problems. Therefore, the article highlights two aspects for research: the hypercube segmentation problem and the directory segmentation problem, and also presents approximation algorithms for them [37]. A framework is also presented that can be adapted to solve any segmentation problem [37].

The study [38] also notes the fact that segmentation belongs to the class of NP-problems. This is due to the huge amount of data that needs to be processed. Moreover, data reduction is considered an NP-hard problem. Cytological images were reviewed for the purposes of the study.

Thus, image segmentation is an important and specific task, one of the stages of which is the extraction of object edges. In some cases, edge extraction can be considered a solution to the segmentation problem. However, object edge extraction should also be considered an NP-problem. Therefore, we next turn our attention to the edge extraction procedure as a type of segmentation, as well as methods for assessing the effectiveness of such procedures.

Object edge detection as a type of segmentation procedure

In Fig. 1 shows an example of a medical digital image for which it is important to most accurately determine the edges of the objects represented in this image.

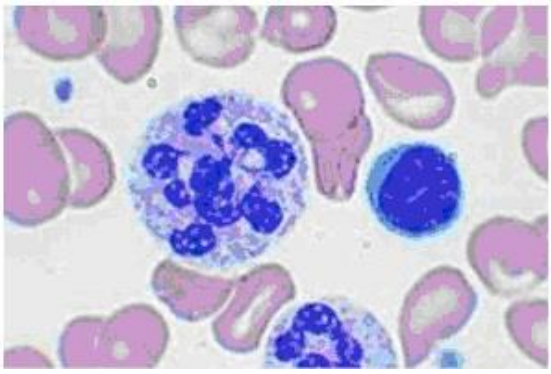

Figure 1: Example of a digital medical image

In Fig. 2 shows images where the edges of objects are selected using the Prewitt and Roberts method.

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889,
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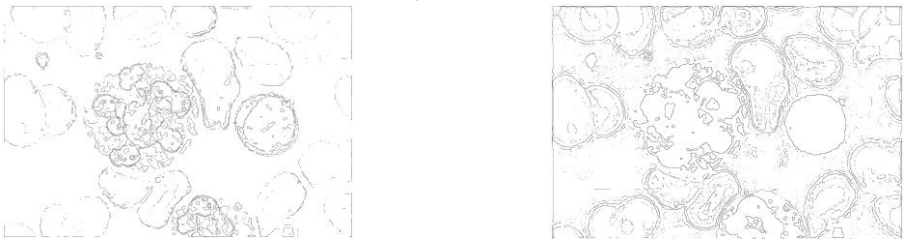
THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME-4, ISSUE-4



a) Prewitt b) Roberts

Figure 2: Extracting the edge of an object using the Prewitt and Roberts method

The importance of considering algorithms for identifying the edges of objects in the segmentation procedure is due to the fact that this makes it possible to localize areas of interest. At the same time, we can consider edge extraction as a specific procedure for dividing the original image. This is consistent with the fact that segmentation in particular is the process of dividing a digital image into many pixels [39]. In other words, the purpose of segmentation is to simplify and/or change the representation of an image so that it is simpler and easier to analyze [40]. Moreover, image segmentation is usually used to highlight objects and boundaries in images [39], [40]. Edge extraction algorithms allow you to do this.

Thus, highlighting the edge of an object, like segmentation, consists of assigning labels to each pixel of the image. Then the result of segmentation is a set of segments or a set of contours selected in the image. In this case, the pixels in the segment are similar in some characteristic or property: color, brightness, texture [39], [40].

However, the result of edge extraction differs depending on the application of some algorithm or approach. For example, in Fig. 2 there is a different degree of edge detail for individual image objects. This allows us to talk about a targeted choice of edge selection method depending on the task at hand. So in Fig. 2a shows detailed contours for cells characterizing megaloblastic anemia. In Fig. 2b shows general detail of the edges of various blood cells. There are also multiple false detections here.

In Fig. 3 shows images where the edges of objects are selected using the Sobel and Canny method.

a) Sobel b) Canny

Figure 3: Extracting the edge of an object using the Sobel and Canny method

There are also varying degrees of edge detail here. It should be noted that for the Canny method, such detail is excessive. There are many redundant detected edge points of objects.

Based on what has been considered, the task arises of assessing the effectiveness of segmentation and choosing a specific approach for identifying the edges of objects. In other words, the problem arises of optimally choosing the appropriate approach for a certain number of iterations. This defines segmentation as an NP-problem.

Generalized sequence of actions in implementing segmentation as an NP-problem

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889,
2024-6.875 ResearchBib IF: 8.848 / 2024

THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME-4, ISSUE-4

First of all, it should be said that the effective implementation of the segmentation procedure largely depends on the formulation of the problem. Here it is important to understand which result is the most acceptable and, therefore, this determines the advisability of using a certain procedure. At the same time, the segmentation problem as an NP-problem can be reduced to a simpler task:

$$SI(NP) \overrightarrow{U} SI, \qquad (1)$$

where

$SI(NP)$ – segmentation of the input image I as an NP-problem;

SI – achieving effective segmentation for the image I;

U – conditional estimates ensuring the achievement of effective segmentation.

In other words, to implement effective segmentation, it is advisable to use some conditional estimates for the choice of the approach used to achieve the goals:

$$I \overrightarrow{U} S, \qquad (2)$$

where

I – original image;

S – effectively segmented image.

It should also be noted that conditional valuations (U) apply to all methods and approaches that are used in a particular case. Then, based on their comparison, the most appropriate approach is selected.

Among such assessments, one should highlight, on the one hand: assessments of segmentation accuracy, and on the other – assessments of image quality [39]-[41].

In turn, among the assessments of segmentation accuracy, as a rule, the following are considered: Jaccard similarity coefficient for image segmentation, Sorensen-Dice similarity coefficient for image segmentation and Contour matching score for image segmentation. However, in all cases it is necessary to select some standard for comparison. In this case, the resulting estimates may differ depending on the chosen standard. This introduces its own problematic aspects when choosing effective segmentation.

At the same time, among image quality assessments, there are: full reference quality indicators, non-reference quality indicators and quality measurements based on test tables. This allows analysis without the use of standards and expands the possible boundaries of the study.

It should be noted the importance of image quality for its further processing. However, in the context of analysis, it is the researcher who determines the importance of the appropriate assessment: segmentation accuracy or image quality. Therefore, such estimates may have their own weighting coefficients, which help to choose the most effective segmentation method.

Then the generalized procedure for solving segmentation as an NP-problem can be considered in the following way:

– the task of using the segmentation procedure is determined, and individual methods for solving it are selected accordingly;

– weighting coefficients are determined for assessing the accuracy of segmentation and the quality of the processed image;

– estimates of the segmentation accuracy and quality of the processed image are calculated, taking into account weighting coefficients for various segmentation approaches;

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889,
2024-6.875 ResearchBib IF: 8.848 / 2024

– based on comparison, the most effective segmentation procedure is selected to solve the problem.

CONCLUSION

The article discusses the problem of effectively using the segmentation procedure for processing and analyzing digital images. In this case, medical images are considered as digital images. At the same time, attention is drawn to the fact that the segmentation procedure is an NP-problem.

To solve this research goal, first of all, it is proposed to take into account the scope of use of the segmentation procedure to solve a specific image analysis problem. At the same time, to improve the efficiency of the segmentation procedure, it is advisable to use estimates of the segmentation accuracy and quality of the processed image, taking into account weighting coefficients for various segmentation approaches. This allows you to achieve the desired effect in using the segmentation procedure and simplify its solution as an NP-problem.

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