Journal of Scientific & Industrial Research
Vol. 82, April 2023, pp. 432-437
DOI: 10.56042/jsir.v82i04.72388

Segmentation Techniques based on Image Quality and Edge Detection Algorithms

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Received 12 June 2022; revised 23 September 2022; accepted 07 October 2022

Segmentation is one of the fundamental tasks in the area of digital image processing and analysis. Segmentation highlights parts of the image that have common features. Such areas of the image are called Region of Interest (ROI). The choice of segmentation algorithm depends on the nature of the origin images and there is no single, universal method that can always be applied. When choosing a segmentation algorithm for a particular image, it is very important to test multiple methods and choose the one that gives the best results. This paper presents a comparison of several segmentation algorithms on different origin images. The comparison was performed based on standard parameters like Mean-Square Error (MSE), Signal to Noise Ratio (SNR), Peak Signal-To-Noise Ratio (PSNR), Structure Similarity Index (SSIM) etc. for image quality assessment. The results of this work can help in the selection of the edge detection algorithm and as a preparation for image segmentation.

Keywords: PSNR, ROI, Segmentation, SNR, SSIM

Introduction

Classification of Segmentation Algorithms

Segmentation algorithms can be grouped on different bases.[1–3] One division is made depending on the need for user interaction when selecting the region, while the other type of division is based on the type of connection between the pixels as shown on Fig. 1. According to the requirement for user interaction, algorithms for image segmentation can be separated into three groups: manual, semiautomatic, and automatic segmentation method.

Manual segmentation methods imply that the extraction of the region of interest is made by the user (or expert) with the support of adequate software. Main disadvantage of these methods is that different users can select different regions, which leads to complications in reproducing the results. Also, the performance of these algorithms requires significantly more time than semi-automatic and automatic algorithms. Automatic segmentation is a method of isolating regions of interest without human interaction. A combination of automatic and manual algorithms creates semi-automatic algorithms. These algorithms initially require human supervision in which the expert points to points that indicate ROI.

Another type of classification of segmentation algorithms is based on the type of connections between pixels. Pixels can be similar in color, texture, brightness, or any other statistical feature of the image. On this basis, there are two methods of algorithms for image segmentation: contextual or global algorithms and non-contextual (algorithms for local region detection). Global algorithms are based on area of pixels with similar characteristics and algorithms for local region detection are based on neighboring pixels. The third type of classification is a hybrid method based on semi-automatic control during processing, and the focus of the work is non-contextual (local). In this type of classification, the user sets the initial value or initial values, and the rest of the algorithm performs detection at the level of the pixel and its environment, and then segment the image. The goal of segmentation is to single out parts of the image that have some common characteristics and that can be further used in the

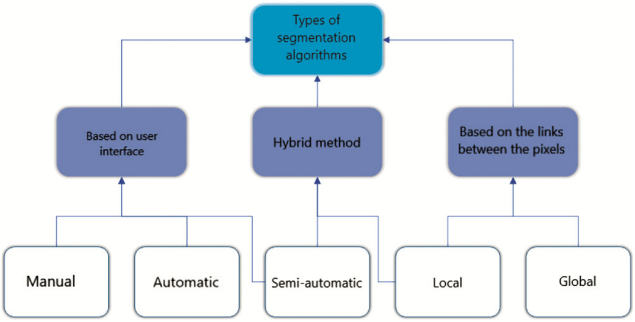

Fig. 1 — Division of segmentation algorithms

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analysis of the image content. Most segmentation algorithms are based on one of two basic principles: the principle of discontinuity or the principle of similarity. Principle of discontinuity single out the chosen parts based on their differences from the other parts of the image, while methods based on similarities do so based on their common features. Almost all segmentation algorithms are based on edge detection algorithms, so it is very important to decide on the appropriate algorithm to be used in edge detection.

The scientific contribution is reflected in the classification and analysis of segmentation models. It should be noted that this kind of analysis has not been done so far. This contribution will help in choosing the type of segmentation in relation to the level of detail of the digital image.

Methodology and Algorithms

In this paper, several segmentation algorithms are implemented on the five types of origin images shown in Fig. 2. The results were analyzed using the Matlab software package. The images under this figure are defined in relation to the complexity of the Level of Detail (LoD), namely: (a) extreme low LoD, (b) Low LoD, (c) Medium LoD, (d) High LoD and (e) extreme high LoD. The values of the level of detail for the observed images are given in Table 1 and are shown respectively in relation to the defined images, i.e. from the extremely lowest value to the extremely highest value. Images with extreme values are important for this work to show the operation of edge detection algorithms in extreme situations of low and high detail.

Fig. 2 — Origin images from website

The experimental images used in this manuscript are standard images used in digital image processing analysis. The goal of this type of study is that the results of this analysis can be compared with the results of other similar works. Depending on the selection of the edge detection algorithm, the defined segmentation regions also differ. This study classified different region segmentation methods without considering the differences introduced by edge detection algorithms. Classified according to segmentation method and compared them. The obtained results are valid under experimental analysis conditions for defined levels of digital image detail. And as such they are comparable to other manuscripts that treat similar analyzes with different levels of detail.

The following segmentation algorithms were used in this paper: segmentation based on pixel level, segmentation based on line, segmentation based on edge, singular value detection, Otsu's thresholding method and growing regions method.

Segmentation based on Pixel Level

During segmentation based on pixel level the origin image is filtered with an Unsharp filter to further emphasize the edges, after which the edges are detected using the Sobel operator as one of the most used image edge detection algorithms.[4,5] Here, the so-called "thickness of the line" is determined in values from 0-1.[(6)] All pixels belonging to the edges are complemented and segmentation is performed based on the double threshold method, where the pixels are joined based on the threshold value. When working with color images (RGB images), segmentation is performed on each of the R, G and B planes separately for each channel. The logical combination of segmentation of all three planes gives the final result. The numerical value of the detection threshold

Table 1 — New detail values for Fig. 2 (a, b, c, d, and e)

Image	LoD value	Pixel level value of the detection		Segmentation threshold value	Otsu's threshold value
		Threshold vdt1	Threshold vdt2		
2a	0.16	0.6125	0.6292	125	0.3212
2b	1.726	0.5011	0.5052	163	0.5003
2c	3.0421	0.4934	0.4974	203	0.5104
2d	6.3703	0.3103	0.3563	219	0.5496
2e	7.9774	0.5423	0.5581	252	0.6274

gained by this method for the five origin images (Fig. 2) are shown in Table 1.

Segmentation based on Line

Line's segmentations are divided into three components: the component of vertical lines, the component of horizontal lines and the component of diagonal lines oriented at an angle of 45° and −45°. By applying segmentation based on line, these three components are obtained one by one.[7,8]

Segmentation based on Edge

In Segmentation based on edge process was performed using Sobel, Prewitt, Canny, Hybrid and LOG operators. Hybrid, Sobel and Canny operators show improved results than Prewitt and LOG operators.[7–10]

Segmentation based on the Detection of Unique Values

The segmentation method based on unique values is based on the detection of unique points.[11–15] The presented single value from the image is used as the segmentation value of the detection threshold. The single values for the origin images (Fig. 2) calculated and numerically presented in Table 1.

Otsu's Threshold Method

Otsu's method is the method for adapting an image in its binary representation.[16,17] Consuming a unique threshold concentration value, this technique splits the image into two modules. The value of the detection threshold is explained by minimizing the adjustment value of pixel within the modules, for both pixel modules that are divided by the value of threshold. If the histogram of the origin image has a bimodal distribution, the results of the Otsu's threshold method will be satisfactory. If the size of the requested object is minor compared to the size of image, it will not be detected by the Otsu's method. The values of the detection threshold are given in Table 1.

The Method of Growing Regions

During segmentation by the method of growing regions, the value of the threshold T is set, on the basis of which the region grows.[18,19] Pixels whose values are fewer than the value of the detection threshold are added to the growing region. If the value of the detection threshold is increased, pixels belonging to the growing region also increase.

Segmentation using the Mosaic Method

This model allows the image, with the help of a hybrid model of edge detection, to be decomposed into segments (mosaic parts), whereby the desired processing can be applied over each segment of the image with different or the same parameters. The proposed model has a high degree of synchronization with other methods of digital image processing, which leaves a wide range of possible uses, and a significant number of published scientific papers during the research shows the real contribution of this dissertation.

Results and Discussion

The previously described segmentation algorithms were tested on a set of 5 origin images (Fig. 2) and the qualitative results are shown below. The segmentation for different parameters is presented in Fig. 3 (i–vii) where the representation are based on: (i & ii) pixel level results for the value of the detection threshold vdt1 & vdt2 respectively, (iii) lines, (iv) edges, (v) detection of unique values, (vi) Otsu's segmentation, and (vii) the resultant images with implementation of growing regions and Hybrid detection method.

Assessment of Digital Image Quality

Image quality assessment data are very important parameters for image quality analysis. After segmentation, the quality of the generated image is compared to the results of different segmentation techniques. In this manuscript, we choose the best segmentation technique for each origin image, with different LoD, through the numerical results of image quality metrics: MSE, SNR, PSNR, EPI, and SSIM.

It is the use of experimental images that provides the possibility of precise analysis of image regions. Already known areas of regions and edges provide the possibility of analysis with the help of the SSIM parameter to evaluate the similarity with the defined methods. The Structural Similarity Model provides the ability to evaluate the similarity between two images, so in this case, an approximate value of 1 gives the highest similarity to the detected regions of the experimental images.

Image quality metrics for the previously described methods for image segmentation are numerically presented in Table 2. All algorithms were tested on the origin images of Fig. 2 (a–e). Based on the results, it can be said that the most suitable for Fig. 3(i–vii)a is the Hybrid method and the growing regions method, because the MSE value is lower than the

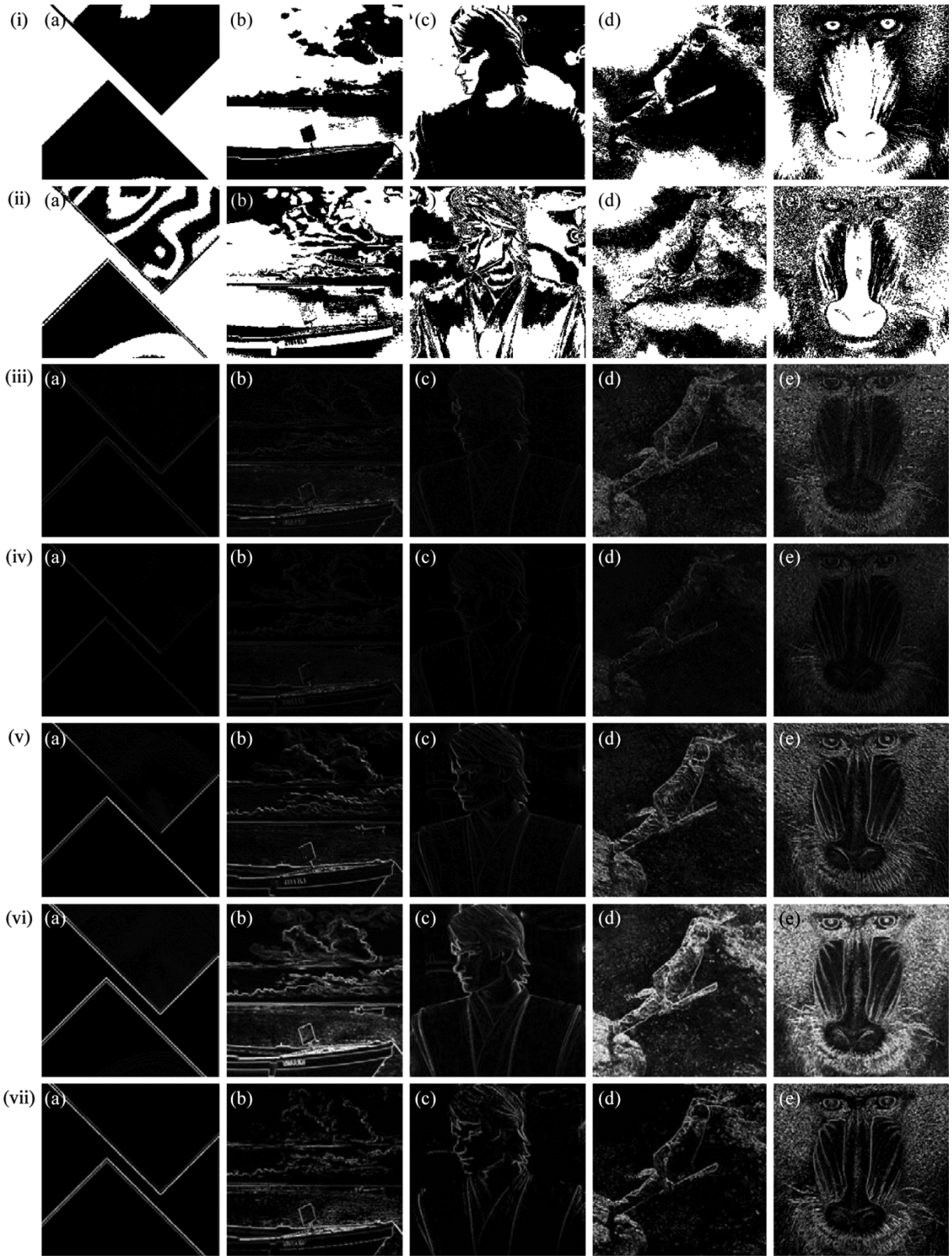

Fig. 3 — Segmentation of origin images of Fig. 2 (a – e) based on: (i) Pixel level output images using the threshold vdt1, (ii) Line output images using threshold vdt2, (iii) Line output images, (iv) Segment-based output segmentation images, (v) detection of unique values, (vi) Otsu segmentation method, (vii) Hybrid image model

Table 2 — Image quality metrics for Fig. 2(a–e)

		Segmentation method						
		Pixel based	Line based	Edge based	Unique value detection	Otsu's	Hybrid	Growing regions
Metrics (a)	MSE	643.0677	670.4458	623.5237	654.4107	655.8292	605.8541	611.1155
	SNR	19.2959	17.8445	17.6601	19.6485	19.5666	19.6667	19.7827
	PSNR	20.0326	20.4231	20.3237	20.2621	20.2545	20.087	20.1487
	EPI	0.7389	0.7352	0.637	0.6759	0.7519	0.7041	0.6948
	SSIM	0.931	0.7939	0.7693	0.8885	0.9371	0.9409	0.9357
Metrics (b)	MSE	691.3172	607.0863	541.6801	561.975	590.0158	595.5651	551.1107
	SNR	19.0172	18.1881	18.9347	19.102	19.029	19.057	18.9121
	PSNR	20.3083	20.0195	20.8359	20.2383	20.2525	20.357	20.3938
	EPI	0.7476	0.6796	0.5525	0.5878	0.6492	0.6591	0.6145
	SSIM	0.8457	0.7263	0.708	0.7254	0.7902	0.8023	0.811
Metrics (c)	MSE	576.1318	572.788	616.8752	645.8874	625.2031	620.1567	624.6294
	SNR	19.6397	19.9073	19.5796	19.7133	19.1065	19.5214	19.7933
	PSNR	20.2649	20.8222	20.4342	19.102	19.6417	20.1453	20.5308
	EPI	0.7082	0.6758	0.5697	0.4955	0.5953	0.5967	0.5933
	SSIM	0.8493	0.8323	0.8229	0.8295	0.853	0.8624	0.8769
Metrics (d)	MSE	684.7713	563.5353	668.2122	651.359	513.7352	501.7514	684.8545
	SNR	20.432	20.5231	18.7737	20.306	20.1552	20.0054	19.4574
	PSNR	20.7452	21.0099	19.2239	20.4518	2,02,795	20.4311	19.9083
	EPI	0.6125	0.635	0.6535	0.5054	0.9272	0.8952	0.5897
	SSIM	0.8586	0.9061	0.9237	0.9264	0.5612	0.9342	0.9093
Metrics (e)	MSE	589.3544	577.4477	576.0983	541.0574	557.7811	529.5581	563.1145
	SNR	19.893	19.4009	19.2052	20.2249	19.7827	19.7887	19.2725
	PSNR	20.3178	19.9304	19.7112	20.4207	20.009	20.0547	19.6583
	EPI	0.5979	0.6532	0.6556	0.5194	0.6391	0.6357	0.9298
	SSIM	0.8817	0.8931	0.904	0.9259	0.9433	0.9347	0.6044

values of other methods, with only the Hybrid method holding a high level of SSIM, while the results of other methods are satisfactory, but not as the two methods mentioned. In a similar way, adequate segmentation methods suitable for the remaining images can be selected. Edge and growing region-based methods are suitable for Fig. 3(i–vii)b (low level of detail), while pixel and line-based methods give the best results in Fig. 3(i–vii)c. The Otsu method, the hybrid method, and segmentation based on line are appropriate for image segmentation for Fig. 3(i–vii)d. The best results in Fig. 3(i–vii)e were shown by the Hybrid Method, while the other methods showed almost identical results.

Conclusions

A big challenge is to choose the right one among many image segmentation algorithms. Some of the main applications in today's software solutions are the recognition of objects in space and maps images, the detection and recognition of persons in forensics, the detection of objects from video surveillance cameras or the separation of regions affected by the disease from medical images. Also, it is big task to find a suitable technique of image segmentation. This manuscript offers a summary of seven different methods of image segmentation into five origin experimental images, and their results are linked using image quality metrics. The results showed a variety of potential applications and a detailed analysis of situations in which detection algorithms can be applied. The attached results represent a reference starting point when deciding when choosing edge detection algorithms for digital image segmentation at different levels of detail.

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