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General Research on Image Segmentation Algorithms

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***Abstract*—As one of the fundamental approaches of digital image processing, image segmentation is the premise of feature extraction and pattern recognition. This paper enumerates and reviews main image segmentation algorithms, then presents basic evaluation methods for them, and finally discusses the prospect of image segmentation. Some valuable characteristics of image segmentation come out based on a large number of comparative experiments.**

***Index Terms*—Comparative research, Image segmentation, edge detection, thresholding techniques, the evaluation of image segmentation**

I. INTRODUCTION

Image segmentation is the foundation of object recognition and computer vision. In order to comprehend image segmentation more deeply, some general knowledge of the structure of image segmentation system is presented first.

As is shown in figure 1, in general, image-noise should be eliminated through preprocessing before the main operation of image segmentation. And there is some specifically-given work (such as region extraction and image marking) to do after the main segmentation for the sake of better visual effect [1].

In image preprocessing, firstly, various color spaces should be transformed into specifically-given color space [3]. Then some techniques such as Gaussian filter are used to smooth images to diminish the influence of noise. As the main body of image segmentation system, image segmentation algorithm determines the result of image segmentation. After that, region merging and region extraction are used to combine unreasonably discontinuous regions. All the efforts above can ensure a satisfying image segmentation result.

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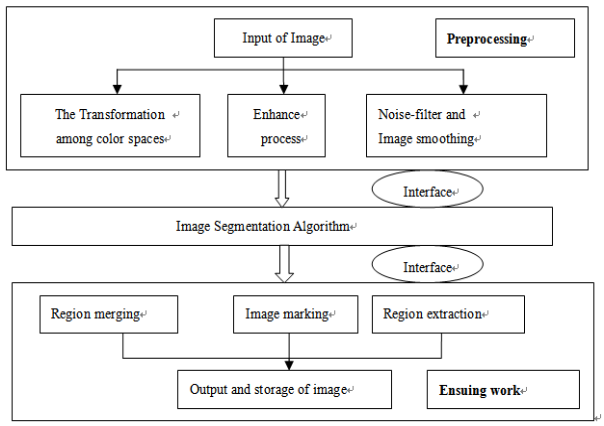

Figure 1. The Structure of Image Segmentation System [2]

In this paper, firstly, main image segmentation algorithms are classified and reviewed; then evaluation and comparison of image segmentation algorithms are discussed in depth based on the reason that evaluation of image segmentation is essential in the aspect of comparing the segmentation algorithm and providing advice for improvement.; at last, evaluation results of typical segmentation algorithms in MATLAB environment are summarized and presented.

II. CLASSIFICATION OF IMAGE SEGMENTATION ALGORITHMS

Image segmentation is generally defined as the basic image processing that subdivides a digital image $f(x,y)$ into its continuous, disconnect and nonempty subset $f_1, f_2, f_3, \cdots f_n$, which provides convenience to extraction of attribute [3]. In general, Image segmentation algorithms are based on two basic principles [4]: the trait of pixels and the information in nearby regions. Most of segmentation algorithms are based on two characters of pixels gray level: discontinuity around edges and similarity in the same region. As is shown in Table I, there are three main categories in image segmentation [5]: *A.* edge-based segmentation; *B.* region-based segmentation; *C.* special-

TABLE I. CLASSIFICATION OF IMAGE SEGMENTATION

Main categories	Sub-classes		Interpretation
Edge-based segmentation	Gray-histogram technique		Partition an image through detecting edge among different regions.
	Gradient--based method	Differential coefficient technique	
		Laplacian of a Gaussian(LoG)	
		Canny technique	
Region-based segmentation	Threshol-ding	Otsu	Exact the objects from the background by setting reasonable gray threshold Ts for image pixels.
		Optimal thresholding	
		Thresholding image	
		…	
	Region operating	Region growing	Partition an image into regions that are similar according to given criteria, such as gray character, color character or texture character and so on.
		Region splitting and merging	
		Image matching	
Special theory based segmentation	Fuzzy clustering segmentation		Introduce Fuzzy Set Theory into image segmentation
	Neural networks based segmentation		It is a learning algorithm imitating the working pattern of neural networks.
	Physically-based segmentation		Utilizing the physical characters of images to partition.
	…		

theory-based segmentation. And some sub-classes are included in the main categories too.

III. EDGE-BASED SEGMENTATION

Understandably, an edge is a set of linked pixels lying on the boundary between different regions, where there are intense discontinuities such as gray change, color distinctness, texture variety and so on [6]. An image can be segmented by detecting those discontinuities. Based on this theory, there are two main edge-based segmentations methods: gray-histogram method and Gradient--based method.

The key to a satisfactory segmentation result lies in keeping a balance between detecting accuracy and noise immunity [7]. If the level of detecting accuracy is too high, noise may bring in fake edges which make the outline of images unreasonable; otherwise, some parts of image outline may get undetected and the position of objects may be mistaken if the degree of noise immunity is excessive.

A. Gray-histogram technique [8]

In order to detect the edge of an image, gray-histogram of the image is divided into two parts using threshold T. Then operations on the image $f(i,j)$ are processed as follows: *(1)*scanning every row in image $f(i,j)$, and comparing gray value of every pixel in the row with T, which results in image $g_1(i,j)$;*(2)* scanning every column in image $f(i,j)$, and comparing gray value of every pixel in the column with T, which results in image $g_2(i,j)$; *(3)* incorporating image $g_1(i,j)$ and $g_2(i,j)$ to get edge image $g(i,j)$.

In the process above, the quality of edge detection depends greatly on the fitness of threshold T. However, it is really difficult to search for the maximum and minimum gray value, because gray-histogram is uneven for the impact of noise. In this case, we can approximatively substitute the curves of object and background with two conic Gaussian curves, whose intersection is the valley of histogram. Threshold T is the gray value of the point at the valley.

B. Gradient-based method

Gradient is first derivative for image $f(x, y)$. When the change of gray value near edge is intense enough and there is little noise in the image, Gradient-based method works well, and segmentation result is adaptive to the direction of gradient. There are three most commonly used Gradient-based methods: differential coefficient technique, Laplacian of Gaussian (LoG), and Canny technique. Among them Canny technique is the most representative one. Canny firstly proposed three criteria for edge detection: optimal detection result, optimal position outcome, and low repeating response [3]. Based on these criteria, he invented “optimal linear filter”, which is first derivative of Gaussian function [3]. The basic idea of Canny technique is as much as follows: firstly filter image $f(x, y)$ with Gaussian function to get smooth image $f(x, y)*G_a(x, y)$. (a stands for scale coefficient), then find the edge pixels by calculating the magnitude of gradient, denoted M_a, and the direction of gradient, denoted A_a. The edge points of the image are the points having the maximum of M_a in the direction of A_a. Equation (1) is the mathematics’ expression of this method.

$$\begin{cases} M_\alpha = \| f(x,y) * \nabla G_\alpha(x,y) \| \\ A_\alpha = \dfrac{f(x,y) * \nabla G_\alpha(x,y)}{\| f(x,y) * \nabla G_\alpha(x,y) \|} \end{cases} \tag{1}$$

However, as the magnitude of gradient is carried out by finding out the zero points of second derivative, those zero points may be both the maximum and minimum of the first derivative. So that the pixels whose gray values change intensely as well as the pixels whose gray values change slowly can be detected equally. Accordingly, it is obvious that Canny technique may bring in fake edge points.

IV. REGION-BASED SEGMENTATION

Edge-based segmentation partitions an image based on abrupt changes in intensity near the edges whereas region-based segmentation partitions an image into regions that are similar according to a set of predefined criteria. Thresholding, region growing, region splitting and merging are the main examples of techniques in this category [10].

A. *Thresholding Methods*

Thresholding techniques are image segmentations based on image-space regions. The fundamental principle of thresholding techniques is based on the characteristics of the image [11]. It chooses proper thresholds T_n to divide image pixels into several classes and separate the objects from background. When there is only a single threshold T , any point (x, y) for which $f(x,y)>T$ is called an object point; and a point (x, y) is called a background point if $f(x,y)<T$.

According to the aforementioned discussion, thresholding can be viewed as an operation to gain threshold T in the following equation:

$$T = M[x, y, p(x, y), f(x, y)] \qquad (2)$$

In (2), T stands for the threshold; $f(x,y)$ is the gray value of point (x, y) and $p(x, y)$ denotes some local property of the point—such as the average gray value of the neighborhood centered on point (x, y). Based on (1), thresholding techniques can be mainly divided into global, local, and dynamic thresholding techniques.

1) Global thresholding: When T depends only on $f(x,y)$ (in other words, only on gray-level values) and the value of T solely relates to the character of pixels, this thresholding technique is called global thresholding technique [5]. There are a number of global thresholding techniques such as: minimum thresholding, Otsu, optimal thresholding, histogram concave analysis, iterative thresholding, entropy-based thresholding, MoM-keeping thresholding and so on.

Minimum thresholding: For simple images, the object and background can be seen clearly in different gray levels. Obviously, in this case, the proper threshold T is the gray value of the valley point between two separate wave crests in image histogram. The problem of searching for the valley of image histogram can be transformed into the task of seeking for the minimum in peripheral curve $L(z)$. Based on the extremum knowledge gained from Advanced Mathematics, we get the minimum gray value z_0 by equating the first and second derivative of L(z) with zero. And z0 is the threshold T. The original image should be smoothened beforehand and the noise in the image should be removed too. Minimum-based thresholding can give birth to satisfying image segmentation if the gray value of object is quite different from the background; otherwise, its segmentation can be unfavorable.

Otsu: From the viewpoint of pattern recognization, threshold T should be the value that results in the optimal segmentation performance between the object and the background. That is to say, suppose a threshold T partitions an image into two parts: f_1 and f_2 , and the optimal T should leads to a maximal mean square error $\sigma^2(T)$. Based on this principle, the optimal threshold T can be calculated. Otsu thresholding is simple, stable and is used broadly.

2) Local thresholding: If threshold T depends on both $f(x, y)$ and $p(x,y)$, this thresholding is called local thresholding [5]. This method divides an original image into several sub regions, and chooses various thresholds Ts for each sub region reasonably. After thresholding, discontinuous gray levels among sub images must be eliminated by gray level filtering technique. Main local thresholding techniques are simple statistical thresholding, 2-D entropy-based thresholding, histogram-transformation thresholding etc.

Simple statistical thresholding: Simple statistical thresholding acquires threshold *T* by pure mathematics equations. Thereby, we can avoid the analysis of histogram, letting alone optimizing function [5]. The equations are shown as follows:

$$e_x = f(x-1, y) - f(x+1, y)$$
$$e_y = f(x, y-1) - f(x, y+1)$$
$$e(x, y) = \max\{|e_x|, |e_y|\}$$
$$T = \frac{\sum_x \sum_y e(x, y) f(x, y)}{\sum_x \sum_y e(x, y)} \qquad (3)$$

In (3), *e(x, y)* stands for the neighborhood character of point *(x, y)*. So it is clear that this segmentation is a kind of local thresholding.

2-D entropy-based thresholding: In 1989, Arutaleb combined one-dimension maximum entropy method with 2-D thresholding proposed by Kirby and his fellows, and invented 2-D entropy-based thresholding. This thresholding uses gray level and local mean gray value (LMGV) to form 2-D gray histogram to choose suitable threshold *T*.

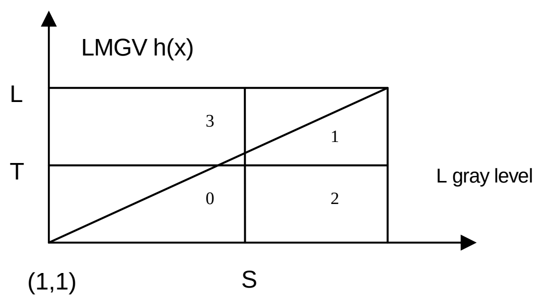

Figure 2. 2-D gray histogram

As is shown in Figure 2, in the area 0 and 1, the gray level of pixels is similar to LMGV *h(z)*, which reveals strong consistency. In this light, those two areas generally belong to object or background regions. With the same logic, area 2 and 3 should be deemed as noise or edge for their weak consistency. 2-D entropy-based thresholding realizes image segmentation by choosing a couple of numerical value*(S, T)*, which maximizes the subsequent entropy between object and background.

3) Dynamic thresholding: If, in an image, there are several objects taking up different gray level regions, the image should be partitioned with vary dynamic thresholds (T_1、T_2、…T_n) [5] , depending on $f(x,y)$, $p(x, y)$ and the spatial coordinates x and y. In general, dynamic thresholding techniques include Thresholding Image, Watershed, interpolatory thresholding and so on.

Thresholding image: The aim of thresholding image, is to create a image B(x,y) with the same size of original image A(x,y) by means of increasing the threshold number until it reaches the pixel number in A(x,y). For example, the thresholding image *B(x, y)* can be formed in this way: Firstly, initialize every pixel in *B(x, y)* with zero; then, calculate the mean gray value T_0 of original image within a smooth n×n (the value n is alterable) template, and endue the center point of the template of image *B(x, y)* with the mean gray value ($B(x, y)= T_0$). Orderly, move the mask from the left- below point in original image to its right-above point and calculate all the gray values in thresholding image *B(x, y)*.

Then, segmentation of original image can be processed by the following equation:

$$\begin{cases} A(x,y)=0; & if \quad A(x,y)\geq B(x,y) \\ A(x,y)=255; & if \quad A(x,y)<B(x,y) \end{cases} \tag{4}$$

Segmentation experiment shows that the segmentation result of this method is good enough. Using noise filter, the result can be even better. However, thresholding image technique indeed has its drawback too: the information near image outline may get lost.

Watershed: An image can be visualized in three dimensions: two spatial coordinates versus gray levels. Based on such a morphological concept, there are three basic types of points [4]: (1) points that fall into a regional minimum; (2) points where if a drop of water is placed at the any location of those points it would invariably fall to a single minimum; (3) points where water would equally fall to more than one such minimum. For a certain regional minimum, the set of points satisfying condition (2) is titled the catchment basin or watershed of that minimum. And the points satisfying condition (3) form crest lines on the morphological surface are called *divide lines* or *watershed lines.*

From all the discussion above, it is clear that the chief objective of this segmentation algorithm is to find the watershed lines. The commonly used way is simple: Assume that a hole is dug in each regional minimum and that the entire topography is flooded from below by letting water rise through the holes at an uniform rate. When the rising water in different catchment basins is about to merge, we built a dam to prevent it. As this process goes on, the topography will eventually reach a state that only the tops of the dams are visible above the water line. These dam's boundaries are the edges extracted by watershed segmentation algorithm.

Watershed segmentation is simple and works well in extracting the outline of the original image. However, as it needs gradient information, the noise in original image will lead to lots of fake regional minimums, which ultimately will result in over-segmentation.

4) Other improved thresholding segmentation algorithms: As thresholding is a basic technique of image segmentation, much attention is given to improve thresholding algorithms. As a result, many new improved thresholding algorithms come into being day in and day out. Considering that traditional Otsu is overly sensitive to the proportion of object and background, literature [10] proposed the Fisher Criterion Function Method. This method is less affected by the object's size and it has a quite stable segmentation performance as well as a fast computing speed.

Relaxation-based segmentation [5] improves the convergent trait of linear equations system by iteratively using local restriction terms. The process of this method is like this: Firstly, divide all the pixels into two types—bright and dark regions according to the probability of gray levels. Then, adjust the probability of every pixel according to the probability of pixels in neighborhood and repeat this adjusting until optimal segmentation result is attained.

Literature [11] proposed a global thresholding algorithm by using artificial intelligence to search valley of image histogram. Besides, many new theories are applied to thresholding segmentation, such as: mathematic morphology, wavelet analysis and transform, genetic algorithm，gray value gradient scattering theory and so on.

Besides the taxonomy of thresholding in this paper, there are several other classifying means, such as: (1) alternative and automatic thresholding algorithms, based on whether manual intervention is needed; (2) iterative and non- iterative thresholding algorithms, depending on whether there is repetition in the algorithm; (3) supervisory and non-supervisory thresholding algorithms, based on the attribute of object and background and whether there are training pixels used for estimating the specific parameter of the image.

B. Region operating [12]

The object of image segmentation is to segment an image into rational regions. In Section III this problem is solved by finding fit boundaries between regions based on discontinuities in gray levels, whereas in Section IV.A the segmentation is accomplished by thresholds based on the distribution of pixel properties, such as gray values and color. In this section, we introduce region operating segmentation techniques based on finding the aim regions directly [13]. This type of segmentation techniques is a kind of iterative algorithms. So its drawback is that it requires lots of computation time.

1) Region growing: As is suggested by its name, region growing is a process that groups pixels or sub regions into larger regions based on predefined criteria [14]. This approach goes on like this: firstly, set a group of "seed" points in original image; then grow regions by appending each seed to those neighboring pixels that have similar properties of the seed (such as gray level or color). Based on this rationale, region growing can be processed in three steps: *a)* choose the right "seed" points; *b)* select a set of similarity criteria; *c)* set up a stopping rule.

2) Region splitting and merging: Rather than choosing seed points, users can divide an image initially into a set of arbitrary, unconnected regions and then merge and/or split the regions in an attempt to satisfy the conditions of reasonable image segmentation. This segmentation algorithm is called region splitting and merging. In this algorithm, splitting as well as merging is used to gain satisfying region segmentation. If only splitting were used, the final partition likely would contain adjacent regions with identical properties. The drawback can be remedied by introducing merging. Region splitting and merging is usually implemented with the theory based on quadtree data [15].

3) Image matching: Image matching is used to match given objects, search special image pattern and so on. Three basic techniques of image matching are: template matching, histogram matching, and form matching. In template matching, a small image (namely a template) compares with the original image so that the same or similar regions in the original image can be detected. Histogram matching carries out image matching by using statistical trait of image histogram. The most commonly used histogram matching techniques are as follows: histogram intersecting, Euclidean distance matching, Method of Moment (MoM) matching, Minkowski Distance matching and so on. Form matching extract the outline of object (a series of boundary points) to approach image matching by level-moving, scale- flexing, and rotating. At present, the most popular form matching techniques are as follows: geometrical parameter matching, crucial wavelet coefficient matching, wavelet outline matching and so on. As wavelet transformation and analysis is an effective tool for a myriad of scales and channels, it is suitable for form matching based on multitudinous scales.

V. SPECIAL-THEORY BASED SEGMENTATION

Numerous special-theory based segmentation algorithms derive from other fields of knowledge such as wavelet transformation, morphology, fuzzy mathematics, genetic algorithm, artificial intelligence and so on.

A. Fuzzy clustering segmentation

In image segmentation, analysis, recognization and other levels of image processing, uncertainty is a key factor that leads to unfavorable results for fixed algorithms [14]. Going further, the result of preceding processing will influence the performance of subsequent processing, which asks for certain degree of flexibility (fuzzy characteristic) in image processing algorithms. Fuzzy Set Theory can be used in clustering and it allows fuzzy boundaries to exist between different clusterings. The main drawback of this algorithm is that it is difficult to confirm the attribute of fuzzy members and it is complicated for calculating in this algorithm [11].

B. Neural Network-based segmentation

Neural network based segmentation is totally different from conventional segmentation algorithms. In this algorithm, an image is firstly mapped into a neural network where every neuron stands for a pixel. Then we extract image edges by using dynamic equations to direct the state of every neuron towards minimum energy defined by neural network [13].

Neural network based segmentation has three basic characteristics [14]: *1)* highly parallel ability and fast computing capability, which make it suitable for real-time application; *2)* unrestricted nonlinear degree and high interaction among processing units, which make this algorithm able to establish modeling for any process;*3)* satisfactory robustness making it insensitive to noise. However, there are some drawbacks of neural network based segmentation either, such as: *1)* some kinds of segmentation information should be known beforehand; *2)* initialization may influence the result of image segmentation; *3)* neural network should be trained using learning process beforehand, the period of training may be very long, and we should avoid overtraining at the same time [15].

VI. EVALUATION AND COMPARISON OF IMAGE SEGMENTATION ALGORITHMS

The research on evaluation of image segmentation can provide crucial reference for those segmentation algorithms, and so this research deserves wide attentions. There are two main instances for objective evaluation of image segmentation: characterization and comparison. Characterization is evaluating image segmentation algorithms by analyzing the effects of the same algorithm on various images while comparison is based on analyzing the effects of different algorithms on the same image. Understandably, the basic requirements are as follows: universal use for evaluation algorithms, its simplification and reliability, and whether referent images or manual intervention is needed. Generally, two basic methods are applied to objective evaluation of image segmentation: analytical technique and experimental technique [16].

A. The analytical technique

The analytical technique evaluates an image segmentation algorithm by analyzing the principle of this algorithm, its complexity, the prior knowledge needed, accurate detecting probability, image resolution and so forth [15]. Naturally, the principle of an algorithm is the processing means and the theory of that algorithm. Its efficiency and computing rate have a great deal to do with its complexity. The analytical technique usually provides supplementary information and supports for other methods of segmentation evaluation and it is seldom used alone [17].

B. The experimental technique

The experimental technique, which is widely used, interprets and compares experiment results of image segmentation algorithms to make an evaluation. This technique can be subdivided into two distinct methods: superiority evaluation method and deviation evaluation method [18].

1) The superiority evaluation method: The superiority evaluation method evaluates an image segmentation algorithm by utilizing human visual trait [19]. It judges the quality of a segmentation algorithm by calculating certain measures based on image segmentation result. The commonly used measures are region uniformity, contrast of regions, region shape and synthetical measure based on ambiguity [19].

The evaluation method based on region uniformity characterizes segmentation result by quantizing uniformity within regions after segmentation. Suppose R_i stands for region i, then gray uniformity (UM) within regions can be expressed as follows [20]:

$$UM = 1 - \frac{1}{\beta} \sum_i \{ \sum_{(m,n) \in R_i} [f(m,n) - \frac{1}{A_i} \sum_{(m,n) \in R_i} f(m,n)]^2 \} \qquad (5)$$

Where β is the normalized coefficient; A_i is the overall number of pixels in R_i.

2) The deviation evaluation method: In this method, firstly a standard segmentation image is provided for comparison criteria. Then the disparity between actual segmentation and ideal one can be calculated to evaluate the image segmentation algorithm [37]. With a comparing test, the deviation evaluation method is generally more effective than the superiority evaluation method [14]. Generally, this method executes evaluation via factors as follows: the probability of mistaken pixels, the position of mistaken pixels, the consistency for the number of regions and so on.

The evaluation method based on the consistency for the number of regions evaluates image segmentation in the manner like this: suppose that *N'* stands for the number of regions after image segmentation and *N* is the number of regions correctly partitioned. Reasonably, we can evaluate image segmentation algorithms by analyzing the difference between *N'* and *N*. One measure of consistency (*F*) is shown as below [24]:

$$F = \frac{1}{1 + p\,|\,N' - N\,|^q} \qquad (6)$$

Where *p* and *q* are both scale parameters.

C. Examples

Although there are plenty of evaluation methods, it is still an important research agenda on how to design evaluation techniques that describe the performance of segmentation algorithms comprehensively and credibly. As many scholars agree, one probable research direction for evaluation methods is to combine artificial intelligence with established segmentation expert system, so that the evaluation results can be utilized effectively for inductive reasoning.

Based on region uniformity, literatures [19] evaluated the segmentation effects of common algorithms on three images, whose objects are a cameraman, a building and a model respectively. And the evaluation result shows that entropy-based thresholding, MoM-keeping thresholding and Otsu thresholding have advantages in the uniformity of image and the shape maintenance of objects. We actualized a myriad of commonly used segmentation algorithms in the environment of MATLAB. Moreover, we evaluated and compared those algorithms' performance through sufficient comparative experiments on image segmentation. And the result of our research is shown in the table below:

TABLE II. COMPARISON AND EVALUATION OF SEGMENTATION ALGORITHMS

Algorithms	Complexity & Processing rate	Suitable images	Segmentation effect	Flaw & Suggestions for improvement
Minimum thresholding	very low/ very fast	Big difference between objects and background	normal	Narrow in application
Histogram concave analysis	low/normal	Little noise	Normal	Not stable; sensitive to noise
Iterative thresholding	normal/ normal	All images	good	Image details are fuzzy
Entropy-based thresholding	very low/ fast	Image with low contrast & complex background	normal	Sensitive to noise
Ostu thresholding	very high/ very slow	Gray histogram have three crests	good/ stable	Combine with other algorithms to improve its performance
Genetic algorithm	very low/ very fast	All images	normal/ stable	Optimize the adaptability function
Genetic algorithm combined with Ostu	low/ fast	All images	excellent	Segmentation speed can be increased by preprocess
Thresholding image	high/very slow	All images	Excellent	The points near boundary may get lost，sensitive to the size of mask.

VII. CONCLUSIONS AND PROSPECTS

In this paper, we classify and discuss main image segmentation algorithms; introduce the evaluation of image segmentation systemically; evaluate and compare basic, practical segmentation algorithms after a large number of comparative experiments. Based on this, we now discuss the prospect of image segmentation. As the basic technique of image processing and computer vision, image segmentation has a promising future and the universal segmentation algorithm has become the focus of contemporary research [35].

Although there are a myriad of segmentation algorithms designed day in and day out, none of them can apply to all types of images and actual segmentation techniques usually aim at certain application [17]. The result of image segmentation is affected by lots of factors, such as: homogeneity of images, spatial structure character of the image, continuity, texture, image content, physical visual character and so on [18]. A good image segmentation algorithm should take all-sided consideration on those factors. Based on the aforementioned statements, we can foresee the trend of image segmentation as follows:

1) Combination of multi-algorithms [15]: For example we can integrate the advantages of edge detection and region-based segmentation by combining those algorithms together and merging the segmentation results according to certain criteria.

2) The application of artificial intelligence [39]: Nowadays, although there are many existing image segmentation algorithms, almost each of them aims at a specific single application and only uses a fraction of image information, which limits their use to a great extent. Fortunately, this problem can be solved by introducing artificial intelligence into image segmentation.

3) The rise of manual alternating segmentation [44]: It is effortless for a human to partition and detect an image. The efficiency and effectiveness of human eyes on image processing is far beyond the level of any computer. The reason is clear and simple: we human use a lot of synthetical knowledge when we are observing an image. Based on this reality, it is optimistic that manual alternating segmentation can realize better segmentation results.

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