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A Review on Image Segmentation Techniques and Its Recent Applications

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Abstract— The technique of attaching a name to each component in a picture so that elements with much the same label have certain visual qualities (pixels, colours, values, patterns, and other features of the image) is known as image segmentation. The output of image segmentation is a series of fragments or patterns taken from the image that collectively cover the full picture. After segmenting an image, classification detects classes in an image on the basic of similarities and differences between detected segments. These two tools together are doing wonders in better object detection in images. Big world has big data, and this big data need robust algorithms for understanding images without a human. This paper summarises the techniques of image segmentation and classification based on their efficiency. Finally, a comparison table shows who performed it better.

Keywords— Image segmentation, Image classification, pattern recognition, edge-based detection, machine learning

I. INTRODUCTION

Segmentation cuts down the image into its constituents (segments). The primary objective of segmentation is to simplify an image by portraying it in a meaningful and easy-to-understand format. Image segmentation is performing wonders in many research areas. Object recognition, automated traffic, security monitoring, knowledge retrieval from big data, separating elements in a complex image are a few applications of image segmentation. In image engineering, *image analysis* stands in the second step among three, the first being *image pre-processing* and *image processing* follows these two.

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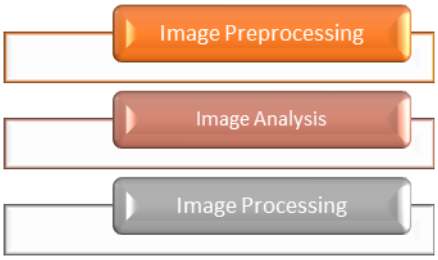


Fig. 1 Image engineering steps

Various image segmentation techniques are introduced in the recent decades. With the large increase of the use of deep learning methodologies, many computer vision experts tend to put a great effort in segmentation analysis. According to the authors, basic segmentation is comprised of two basic approaches, (I) Discontinuity detection approach *e.g., Edge based* (II) Similarity detection approach *e.g., region based*. If we look closely to the methods which help in image segmentation, they are mainly 7 in number, namely, (i) *Thresholding Method (ii) Segmentation based on features (iii) Segmentation based on clustering (iv) Segmentation based on edges (v) Segmentation based on layered architecture (ANN) (vi) Segmentation based on regions (vii) Watershed Techniques (viii) Hybrid techniques* ([1], [2]).

II. IMAGE SEGMENTATION TECHNIQUES

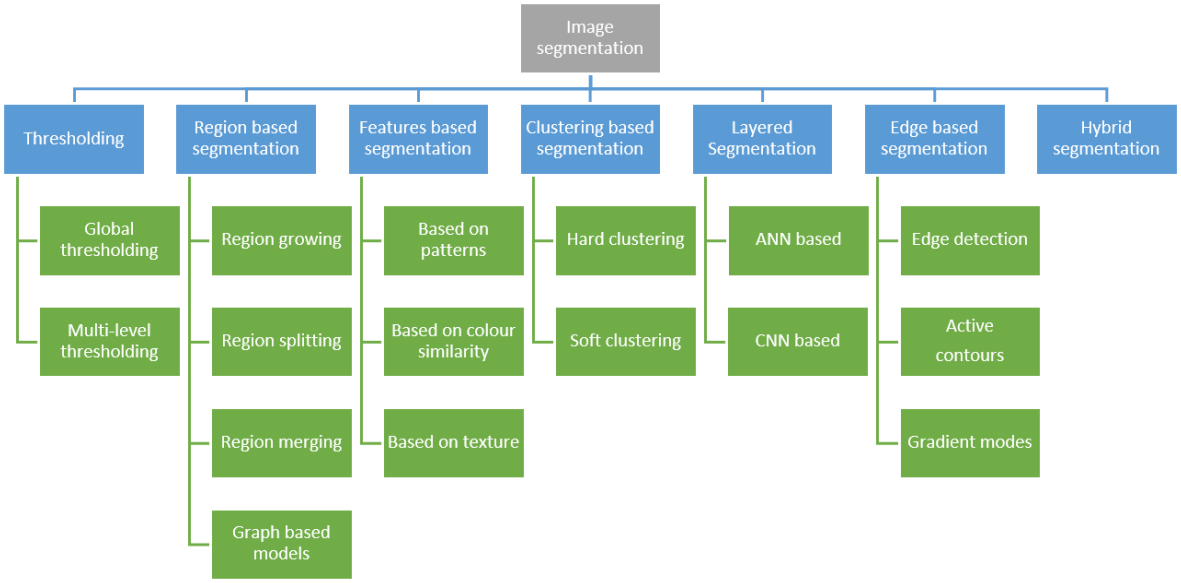


Fig. 2 Image segmentation techniques

A. Edge Based Segmentation.

The boundary between two homogenous regions is edge [3]. While exploring and discussing the *Edge detection* technique, [4] worked in soft computing under three approaches, (i) *Fuzzy logic*, (ii) *Genetic*

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Algorithm and (iii) *Neural Network*. Different edge detection methods behave differently under certain conditions. [5] Edges are of four types, (a) step, (b) line, (c) ramp and (d) roof.

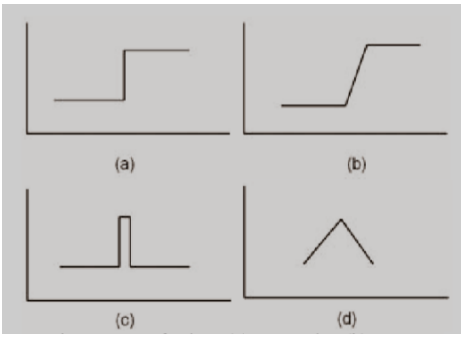


Fig. 3 Types of Edges

[6] Canny Edge detection is considered as a benchmark for edge detection which consists of four steps:

1. Smoothing by Gaussian filter
2. Sobel operator for finding the directions in 2-D plane
3. Non-maximal suppression for omitting the non-edge areas
4. Hysteresis, that eliminates the broken edges

These four are the conventional points, every edge-detector follows. If the edges are detected, measuring the performance analysis is a subjective approach. Many adaptive edge-detectors are also discussed in literature and are recommended based on their peculiar variance in nature. Example Study using Edge detection method: Though much precise results are obtained by the edge detection in segmentation, still noisy images can be difficult to produce fruitful results. Active contour models are used widely to do the job. Level set of the weighted length and region coefficient along with the multi local statistical information model is used.

B. Thresholding.

Minimizing the background noise to capture the useful information stored in an image pixel leads to thresholding. It is a specific form of image segmentation in which the image pixels are divided into group based on some value [7].

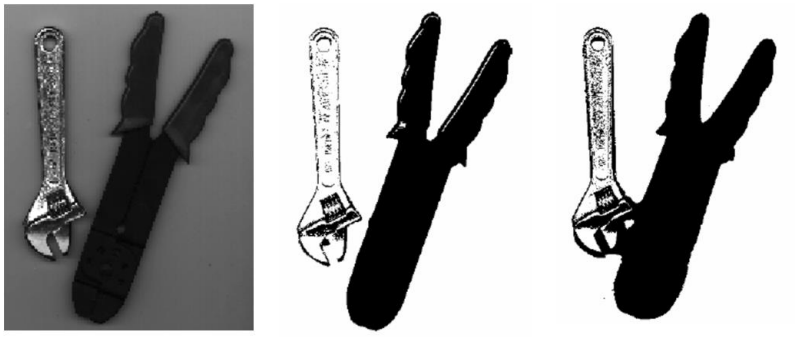


Fig. 4 An example of thresholding technique

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1) *Global/Fixed thresholding:* Global thresholding makes the image bimodal analysis, such that the background value and image value are easily separable. Assume the following two values for image g, g(x,y) against the background p, p(x,y). The value of threshold remains stiff throughout:

$$g(x,y) = \begin{cases} 0 & f(x,y)<T \\ 1 & f(x,y)>=T \end{cases}$$

2) *Multi-level Thresholding:* Several researchers have used different levels of thresholding to ensure better results in their image analysis specially segmentation Choosing a best level of thresholding has been considered a serious issue in recent studies, hence relying on either a bi or multi-level. To solve the issue some metaheuristic techniques such CS, BAT, ABC, FF, SSO, WOA, MFO, GFO and PSO are introduced each of which uses different values of objective function with different CPU time, SSIM and PSNR [8]-[14]. Moreover, Rényi's entropy and BAT algorithm (Bat-Rényi's algo) in which bi-level Rényi's algorithm is improved using Bat algorithm to overcome its accuracy and quality issues [15]. An experiment performed in 6 different satellite images and compared with two ground truth images; the fitness of the proposed model got 60% better. According to a new opinion proposed by [16] thresholding has mainly two methods, parametric and non-parametric. The second one is considered more reliable due to its improved accuracy rate but uses multiple values of threshold. As exhaustive search results in inefficiency, several evolutionary algorithms are introduced, among them Human Mental Search (HMS) is one of the latest. Multilevel thresholding is one of the main concerns in such algorithms, where several bids or solutions to the problem are gathered and a cost analysis is performed. Not only evolutionary algorithms, many CNN based techniques also adapt thresholding [17]. Additionally, [18] recently proposed FCN based image segmentation model using thresholding. The model provides pixel-wise state-of-art sematic (remote sensing classification) image segmentation as performed on the DSTL dataset.

C. Region Based Segmentation.

In this type of segmentation (otherwise called 'Similarity based segmentation') [19], leaning to different criteria, an image is divided into its constituents (usually patches) based on region growth similarities in pixels *[20]*. For this type of segmentation, pixels are always closed under defined threshold. Many other branches are introduced in region-based image segmentation for example, region growing, and region splitting, merging, thresholding. Otsu's algorithm is one the biggest example of this type of segmentation. Many ideas are emerged after Otsu's algorithm, like, improved Otsu, Otsu and K-mean, improved threshold in Otsu and Otsu's improved histogram. Nevertheless, a few performed better and few failed but all these studies heed to similar patch detection in a multi-model image. A comparison performed by [23] concluded that region-based segmentation has a drawback of limitation to boundary whereas the Edge-based detection doesn't require the boundary and just rely on pixel values inside the image. A contour-based deformation technique based on region segmentation is proposed by [21] in ehich some vertical polygone connecteors define the region and help in segmenation. A herarical and metaheuristic approach is devised by [22] for image segmentation to improve visual qualities of the image and its regions.

D. Features-based clustering.

Another eminent approach for image segmentation is clustering, where all relevant and non-repeating information is grouped based on some reliable facts. Clustering is of three types, (1) hard clustering, (2) soft clustering and (3) watershed-based *methods* [24]. Machine learning plays a viable role in such grouping. Feature extraction is mainly categorized as: (1) filer model, (2) wrapper model, (3) embedded model and (4) hybrid model [25]. Most of the recent research focus on the hybrid to perform better results. Clustering is a challenge when we extract feature in a nightmarish medical image or in an adversely captured satellite image. Hence, many research professionals are adopting efficacious ways to cluster the image information based on its features. A fuzzy C adaptive clustering method for brain lesions detection is proposed by Sucharitha et al. [26]. Web documents are also being clustered these days using features [27]. Biomedical images are being clustered based on their features [28]. Recently many applications of features based clustring are revolutionizing the bioinformatics. Python based library, FEATS, introduced by Edwin Vans in 2020 is an example of its application. Many ANN and CNN algorithms are also working to take features-based clustring to next level. Another synthetic model is proposed by [29] where a blend of novel Gaussian filter is rummage-sale to quotation the beneficial geographies from image. It gave a new dimension to the component-based feature extraction when joined with Markov Chain Monte Carlo. Wavelet technique is also used for image segmentation. Probably the very new method of its era introduced in [30] highlighted a new blend of Active contour, Fuzzy c-

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mean and K-mean that generated a new concept of wavelet in feature extraction. The input image goes through the global wavelet decomposition and the results are passed through a tune coefficients weight algorithm, finally the clustering is performed, and we get the output image with features extracted.

E. Layered Segmentation Techniques.

Layered segmentation is other than all the blocked segmentation techniques. Many times, in medical imaging we need to focus even more deeply on certain images [31]. They also have wide range of use in machine learning algorithms where training and testing data is compared with some ground truth in each layer to get desired results. Recently an analysis performed by Moeskops et al. discussed the same issue. They compared a single layered CNN model against a multi-layered model and concluded that the later performed better. Similarly, ANN (Artificial Neural Networks) are also incorporated in image segmentation which is based on simulation of leaning process. An example of such technique is a hand-writing recognition model used by [32]. Precedent of every OCR recognition is image segmentation. Hand-written sentences are segmented using static segmentation and the recognized characters are fed to the ANN layer to match them with actual letter. Another layered prefecture proposed by [33] helped in separating the moving foreground and still background in a video stream. A completely independent wrist and forearm scanner that recognises joint locations across or more a 60 minutes of ongoing gesture recognition video frames [34]. Layered ANN segmentation is used to construct a unique approach for pragmatic use of the presented geometric approaches in stereo depth reduction [35].

F. Hybrid Segmentation Models.

Many medical images gather noise and unwanted data as they are captured, so merely adapting one of the segmentation techniques may not always be fruitful. Several recent researchers have designed a blend of famous algorithms to sustain premier results [36]. One such technique is recently instigated by [37] in which a hybrid energy functional is proposed to minimize the risk of important data loss in medical images. A comparative analysis among the four pre-designed models (global CV, LBR, LHIF and SLRI) and their proposed model led to the belief that combining the two techniques (adaptive global term and local correction term) made the results not only efficient but were more canonical and reliable. A conditional RM and Bayesian model is another example of a state-of-art algorithm for semantic segmentation [38].

Another robust LiDAR model is introduced by homogenizing SqueezeNET and Octconv. This type of segmentation is best suitable for pixel-wise image analysis where different objects coincide. The proposed hybrid approach works on road scene and the model is as follow:

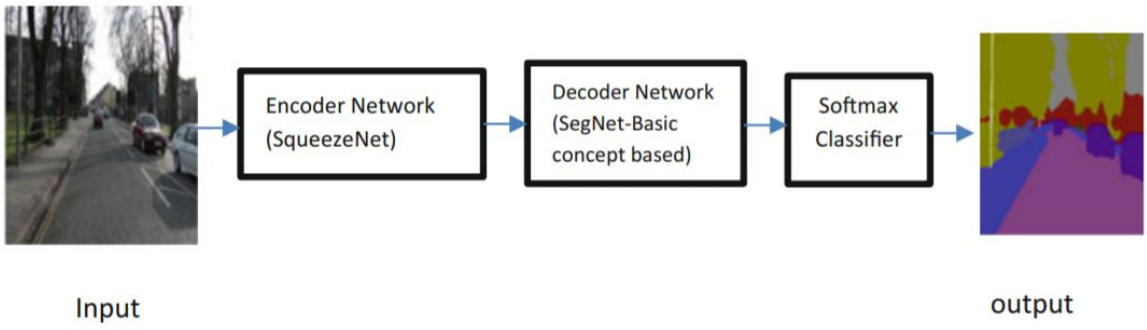


Fig. 5 Hybrid model LiDAR proposed by [39]

In another model, 3 level image pre-processing a heavy image analysis phase used a blend of multi-level techniques; Marker watershed, Particle swarm, Fuzzy C-mean clustering, and Iteration image strips, finally the optimal segmentation results are obtained that really enhanced the segmentation results [40].

Apart from the methods discusssed above, image segmentation also uses Partital Diffrential equations, Variational methods, watershed methods, multi-scale methods, models based methods, semi-automatic methods, multi-spectral method and many others. Image segmentation has many applications from driving traffic on road to handling gadgets in your hand. Here is a comparison of the famous image segmentation methods and how they distinguish eachother though performing the same task:

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TABLE I

COMPARISON OF SEGMENTATION TECHNIQUES

Segmentation technique	How it works	Advantage	Disadvantage
Thresholding	Out of a greyscale image, thresholding leads to a binary image. Setting two or more values for image and its background is thresholding	For a uniform image, this method works nicely. Additionally, it requires no previous knowledge	Thresholding always requires new processing time for new inputs, no savage for pre-saved data
Region based segmentation	Dividing image in several regions. It looks at pixel values more precisely while defining a region	Similarities in the same region can be easily detected. Helps in filling missing information	Restrictions of regions and boundaries
Features based segmentation	All pertinent and non-recurring information is grouped based on some solid facts	Works well in real time scenarios	These methods are outdated. More time consumed in initializing objects. Not obvious for optimal window size
Clustering based segmentation	Based on homogenous clusters in an image	Strong predicted results based on clustered values	In case of a single wrong labelled feature, many important information can be lost. Computational complexity
Layered segmentation	Based on neural networks and learning processes	Readymade programming libraries help to perform so many tasks in less to no time	More understanding of the underlying neural network required
Edge based segmentation	Works on the discontinuity in an image	No need to have a beforehand knowledge, better image contrast will do the job. It is supported by many learned algorithms	More edges mean more difficulty or may lead to wrong segmentation results
Hybrid techniques	A mixture of different segmentation techniques	Use good qualities of different techniques	More time consuming when dealing with two or more scenarios

III. LATEST ADVANCEMENTS IN IMAGE SEGMENTATION APPLICATIONS

This section presents the applications of image segmentation and recent advancements made in segmentation.

TABLE 2

LATEST IMAGE SEGMENTATION TECHNIQUES

Researcher	Image segmentation technique used	Findings in paper	Year
[41]	Hybrid segmentation (Prostate segmentation)	Parametric and non-parametric classification approach investigated	2012
[42]	Context based segmentation	Video based data analysed and segmented and accuracy increased	2006
[43]	Edge-based detection and Global regularization parameter	Non-reiterative inverse image interpolation technique	2005
[44]	Multi-level thresholding	Colour image segmentation for breast cancer cells images	2016
[45]	Cluster based segmentation	Automatic brain tumour segmentation in PET images	2013
[46]	Clustered based segmentation	Algorithm for 3D cell cluster splitting	2011

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[47]	Clustered based segmentation	Mammographic image segmentation for massive volume of data to gain 94% accuracy	2014
[48]	Region based segmentation and contour model	Bayes theorem used for improved segmentation for images that have concentration inhomogeneity	2021
[49]	Region based segmentation	MMFO algorithm for less computational time and better accuracy for image segmentation	2022
[50]	Hybrid segmentation (knowledge based)	Improved statistical modelling for cerebral arteries	2019
[51]	Pattern recognition and features based segmentation	Polyp counting of wildlife images and underwater images containing fishes	2020
[52]	Edge based segmentation	Study for microstructural features for nano and atomic scale characterization	2019
[53]	Thresholding and cuckoo search	Quality segmentation enhancement	2013

IV. CONCLUSIONS

A review of image segmentation techniques, their current applications, and a general comparison between them is summarized in this paper. With no doubt image segmentation is doing wonders for us in better understanding of unseen image and it has so many applications around us. The discontinuous and similar techniques used in image segmentation which started back in 90s is still of great interest for many upcoming researchers. With all its great implications, we still not have a single method suitable for all types of images.

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