

# A Review on Image Segmentation

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**Abstract.** Along with computer technology, the demand of digital image processing is too high and it is used massively in every sector like organization, business, medical etc. Image segmentation enables us to analyze any given image in order to extract information from the image. There are numerous algorithm and techniques have been industrialized in the field of image segmentation. Segmentation has become one of the prominent tasks in machine vision. Machine vision enables the machine to vision the real world problems like human does and also act accordingly to solve the problem so it is utmost important to come up with the techniques that can be applied for the image segmentations. Invention of modern segmentation methods like instance, semantic and panoptic segmentation have advances the concept of machine vision. This paper focuses on the various methods of image segmentation along with its advantages and disadvantages.

**Keywords:** Machine vision, Image Segmentation, Edge detection, Region growing, clustering, PCA, SVM, GA, Histogram, Fuzzy-c-means.

## 1. Introduction

Digital image processing is an area of study about digital images and Image segmentation makes it possible to analyze the given image in order to find something interesting. In machine vision, segmentation is the method of dividing a digital image into different parts; moreover segmentation can be seen as a procedure of labeling each and every pixel in an image so that pixel or pel having the similar class label having definite visual characteristics similar. Outcome of the segmentation process is a collection of segments that together cover the whole image [1]. Think what is the initial step you will take when you are trying to cross the road; we usually look right and left to have look on the vehicle on the road, and take our decision. Human brain is capable of analyzing the whole matter, in milliseconds, that what type of vehicle (bus, car, auto, truck etc.) is coming towards. Here the question arises that can machines do the same thing? and the answer was 'no' till a few years back but the advancements in machine vision have changed the concept, now we are capable of developing machine vision models that can spot objects, figure out their shape, guess the object direction, and it can do many other things. Now you might have got the idea about the powerful technology behind self-driving cars! [2]. Invention of modern segmentation methods like

instance, semantic and panoptic segmentation have advances the concept of machine vision.

## 2. Literature review

There are various types of segmentation method and some of the methods are mentioned in the given Figure 1 and a detail about each method is discussed in the paper.

1. **Unsupervised Image Segmentation:** It does not need any previous knowledge about the image and it does not require training data hence it is also called nearest neighbor segmentation.

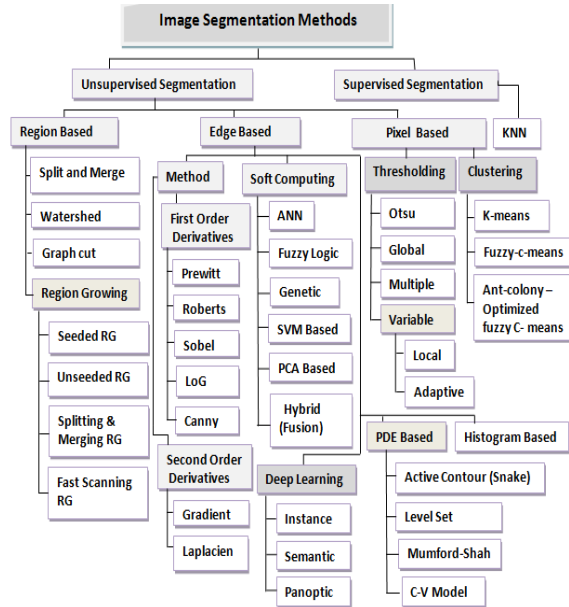


Fig 1: Segmentation Methods

- 1.1 **Region Based Segmentation Method:** In this method every pixel of an image is being checked in incremental fashion and it does require using adequate thresholding method. Types of Region based segmentation are discussed below.
  - **Split and Merge:** This method is applied to the whole images. Split region is a top-down process and in this method instead of selecting kernel points, image can be partitioned into a set of random unconnected regions and then combine the regions [3]. Advantage: It is easy method. Disadvantage: It may lead to over segmentation.
  - **Watershed Segmentation:** It is a morphological gradient based segmentation that partition segmentation areas drained by different river system. It is a very effective and accepted segmentation technique and it can offer more precise segmentation with little computational resources [4]. Watershed is excellent to handle objects with blurry edges and uniformed background [5]. Advantage: No seed is required and processed regions are connected and it can also find best possible boundaries [6]. Its range is very good. Disadvantage: It is sensitive to noise and inhomogeneity [5].
  - **Graph Cut:** It has got very much concentration as it uses both boundary and regional information. Moreover, graph cut based method is effective because it can get globally optimal result and it is also applicable to segment dimensional image. There are three types of method; i.e. interactive-based, speed up-based and shape prior-based graph cut [6]. Advantage: It is efficient to the natural image without any prior information. Disadvantage: Memory utilization increase as the image size increase.
  - **Region Growing:** In this approach of the segmentation initial seed pixel is identified in the image and then the region is growing based on the pixel value. It is typical sequential region segmentation, and its fundamental thought is to have similar character of the pixels together to shape a region [7]. It has four types; i.e. Seeded,

unseeded, Region splitting and merging and fast scanning. Advantage: various criteria can be applied at once and it provides best outcome with a smaller amount noise. Disadvantages: It may produce over segmentation image due to noise.

1.2 Edge Based or Boundary based: This type of method transform an image into edge images by altering the grey value in the images. An object is made up of various part of diverse color levels and lack of continuity shows the presence of edges. An edge is the local changes of image intensity value and an edge appears in the boundary between two parts of the image [7]. It has various types as discussed below.

1.2.1 First Order Derivatives (FOD): Derivative is defined as differences and it is used to detect abrupt and local changes to the images so, FOD and second order derivatives (SOD) are suitable for this purpose. FOD are good to select the strongest edges by thresholding the gradient magnitude. Advantage: FOD usages simple pixel differences for calculating changes in gray intensity. Disadvantages: It is very responsive to noise and generate very thicker edges. FOD can be represented using following equation (1).

$$\frac{df}{dx} = f'(x) = f(x+1) - f(x) \dots (1)$$

Prewitt filter, Roberts Filter, Sobel Filter, LoG (Laplacian of a Gaussian) Filter, Canny filter etc. are types of FOD filters.

1.2.2 Second Order Derivatives (SOD): It is more refined methods for automatized edge detection. It does boost fine details (including noise) as compare to FOD [8]. In both the step and the ramp edge that is performed in second derivatives has opposite sign (positive to negative or negative to positive) as it transition inside and outside of an edge and this dual edge effect is an important characteristics of SOD [8]. Sign of SOD is also applied to find out that whether an edge is transition from dark to light (positive second derivatives) or from light to dark (negative second derivatives) where the sign is observed as we move into the edge [8]. SOD can be represented using following equation (2)

$$\frac{d^2x}{dx^2} = f''(x) = f(x+1) + f(x-1) - 2f(x) \dots (2)$$

- Gradient operator: This operator identifies edges after searching for the minimum and maximum value in first derivatives of an image [9]. Advantage: It has a robust average response in area of ramps and steps transition than does the laplacian [8]. Disadvantage: The response of this operator to fine details and noise is less than the laplacian and can be lesser further after smoothing gradient with an average filter [8].
- Laplacian operator: It is a two dimension measure of second derivative of an image. It detects regions having quick intensity variation and therefore most often used for edge detection. Zero crossing is the points where the laplacian changes sign (where value passes through zero) to find edges [9].

1.2.3 Soft Computing based segmentation

- Artificial Neural Network (ANN): It is a processing system which is inspired by the human neurons. ANN is made up using various layers where the first layer is input layer in which input is given using matrix and last layer is output layer and in between layer are called hidden layers. There are various activation functions like sigmoid, binary, ReLU (rectified linear unit) etc. ANN learn through activation function and learning rate must be between [0, 1] and the error it is suggested to be below 0.1. Advantage: It works very well in some field where other segmentation method does

not like it performs very well in face recognition. Disadvantage: It need so much training data and time to train the ANN model.

- Fuzzy Logic: L A Zadeh invented Fuzzy set theory in 1965 to deal with imprecise information. Let  $Z$  be a collection of objects and genetic object of  $Z$  represented by  $z$ ; like,  $Z = \{z\}$ . Fuzzy set  $A$  in  $Z$  is illustrated by membership function,  $\mu_A(z)$ , that is attached to each element of  $Z$  and is a real number in the interval of 0 and 1. The value of  $\mu_A(z)$  in  $z$  represents the ranking of membership of element in  $A$  [8]. A fuzzy set in is formally defined as equation (3).  $A = \{z, \mu_A(z) | z \in Z\} \dots (3)$
- Genetic Algorithm (GA): GA is eventually applied for solving the optimization problem and it selects the initial population and then it repetitively changes a population of individual. In every step, it chooses population randomly from the existing population to be used as parents and then parents produces the children; used for the next generation and this process continues until we get the population repeated. GA segments an image by using an optimization function without using any threshold values and it can produce more accurate results than basic segmentation methods and it provides faster convergence to the best possible solution [10]. Genetic algorithm involves three steps i.e. selection, crossover and mutation.
- Support Vector Machine (SVM) Based Segmentation: SVM is derived from the support vector classifier. It is derived from enlarging the feature space using kernels. The kernel approach is just a well-organized computational strategy for applying a non-linear boundary between classes [11]. Both of the classifications (binary & multiclass) are used in SVM [11].
- Principal component analysis (PCA) Based Segmentation: PCA is mainly used for dimension reduction of an object and used for filtering of different features and overthrow by analyzing the principal component. Karim, T. F. et al. (2010) [12] has used PCA based segmentation for face recognition and it has been observed that they got good result instead of having some shortcoming of the system [12].
- Hybrid (Fusion) Based Segmentation: Hybrid means combination of two or more than two techniques for the image segmentation like PCA have been used with K-Means clustering for doing the segmentation and histogram have been used with k means cluster for segmentation [13].

#### 1.2.4 Deep Learning Based Segmentation

- Instance Segmentation: Instance Segmentation is a futuristic segmentation and its objective is to discover particular object in an image and to create a mask around the desired objects shown in figure 2(b) [2]. It produces mask in place of a bounding box [2]. Instance segmentation does not aim to label every pixel in the image unlike semantic segmentation, which tries to assign label to every pixel in image [2]. In the below figure one sheep is different from the other sheep and both have been assigned different color.
- Semantic Segmentation: This type of segmentation is important for the task where the analysis of image is very much important. The basic idea is to associate each and every pixel of an image with a class label, (like car, road, ocean, or flower) [14]. It assigns a same color label to the objects belongs to the same class as shown in the figure 2 (d). Semantic segmentation is used in self-driving cars, industrial inspection, medical imaging etc.

- **Panoptic Segmentation:** Panoptic segmentation combines both instance and semantic segmentation. Here the basic idea is to merge different modules of instance and semantic segmentation but it introduces the more challenges (see figure 2 (e)) [15].



Fig 2: (a) image (b) after applying Instance segmentation [2] (c) image (d) after applying semantic segmentation [14] (e) after applying panoptic segmentation [15]

- 1.2.5 **Histogram based segmentation:** It is fundamentally a region growing method, where histogram features are used for growing. Histogram feature calculation is a most important for algorithms and it also saves time of computation [16]. It is applied on digital image intensity level lies between 0 to L-1.
- 1.2.6 **PDE Based Image Segmentation:** PDE is based on mathematical equation. PDE uses two or more independent variables, an unknown function that is dependent on variables, and partial derivation of the unknown function with respect to the independent variables. Methods based on PDE are; Active Contour model, Mumford Shah Model, Level Set, C-V Model.
- 1.3 **Pixel (Point) Based Segmentation:** It is the formal techniques of segmentation and it is done based on the pixel information like gray level value etc.
  - 1.3.1 **Thresholding based Segmentation:** It is a popular segmentation technique, it separate foreground from the background, where objects are seen very clear [17]. Using thresholding, one can extract the object from the background [8]. It has four type i.e. Otsu, global, multiple, variable thresholding etc.
  - 1.3.2 **Clustering:** Clustering is a method of separating an image into different subgroup based on the some similarity. Clustering is of two types; supervised and unsupervised clustering. K-Means is one of the most frequent used algorithms.
    - **Fuzzy-c means (FCM):** FCM is most frequently used unsupervised method and it is mostly used in medical imaging [18]. It allows each data to pertain to more than two clusters [18]. Advantage: It takes the advantage of fuzzy logic to form clusters, so it is suitable for segmenting the complex images like medical image etc.
    - **Ant-colony optimized fuzzy c- means:** This is the modified version of fuzzy c means clustering. Here number of center and center value is obtained by ant-colony optimization and then the fuzzy-c-means is used for classifying the remote sensing image. Visual range of ant is small so in the beginning search is blind. However, the ant leaves pheromone on the path [19].

### 3 Conclusion

Image segmentation is one of the important and fundamental steps of digital image processing and it has been seen that many different segmentation method is being invented day by day and none of the method is good; it means choosing a method for segmentation highly depends on type of problem being addressed. Inventions of

modern segmentation like instance, semantic and panoptic have made it much possible to develop self-driving car because now it is possible to build models that can well predict object, their shapes and the direction the object will move towards so image segmentation plays a vital role in development of computer vision system.

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