# Application Centric and Algorithm Centric Classification of Image Segmentation Algorithms

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## ABSTRACT
Image segmentation is critical for many computer vision and information retrieval systems. Although lot of advancements has been made in this area, but there is no standard technique for selecting a segmentation algorithm to use in a particular application. Two different segmentation algorithms will produce completely different segmentation results when applied to same image, which in turn affects the performance of the application. The diverse requirements of systems that use segmentation have led to the development of segmentation algorithms that vary widely in both algorithmic approach, and the quality and nature of the segmentation produced. The objective of this paper is to categorize the different segmentation algorithms according to the characteristics of algorithms and according to the characteristics of the application for which they are used.

## General Terms
Image Processing, segmentation

## Keywords
Image segmentation, perceptual grouping, algorithm centric, application centric

## 1. INTRODUCTION
Like many complex computer vision problems, image segmentation is ill-defined. A common definition of segmentation is that it is the process of partitioning the set of pixels in an image into several disjoint subsets, according to a set of predefined criteria. Image segmentation is also defined as the process of dividing an image into different homogeneous regions but the union of any two adjacent regions is not homogeneous [1]. [2] describes segmentation as the process of portioning an image into regions that are in some sense homogeneous, but different from neighbouring regions. All these definitions use the concept of homogeneity, which often corresponds to identifying regions containing features that are relatively nearby according to a prescribed distance measure.

Segmentation can also be considered as an algorithmic attempt to mimic a human interpretation of an image, which is known as perceptual grouping. With this view point, Fu and Mui [3] states that "the image segmentation problem is basically one of psychological perception, and therefore not susceptible to a purely analytical solution". Martin et al., [4], and Salembier and Garrido [5] also argue that perceptual grouping is hierarchical in nature, and consequently a flat partitioning of an image is insufficient for representation of a perceptual segmentation.

Other authors admit that both viewpoints are valid. Shi and Malik concede that final goal is perceptual; however, they mean that the scope of segmentation should be limited to robust homogeneity–based hierarchical grouping of low level features, and that high level reasoning can be used at a later stage to identify the semantic entities [6]. On other hand, Adamek et al., state that segmentation is the process of portioning an image into a set of semantic entities or homogeneous regions [7]. Image segmentation can have a more physical definition; if an image is thought of as an observed phenomenon induced by physical objects and lighting conditions, then segmentation is a process of attempting to infer some knowledge about the model that caused the observed patterns, i.e., retrieving a model of the image generation process [8].

It is clear from above that there is lots of variation in what is understood to be the scope and definition of image segmentation problem. Image segmentation is usually one of several components in a larger information processing system, and the variation observed in the definition of image segmentation is mirrored in the variation in requirements on the image segmentation algorithms in these systems. The research in the area is vast: lots of papers, studies and reports have been published investigating new methods for image segmentation and their applications. The nature of the problem has inspired diverse algorithms, drawing from fields of research that include statistics, machine learning, graph theory and psychology. The applications of image segmentation are as varied as the algorithms; such as: bio-medical image analysis, multimedia information retrieval, image understanding and machine vision.

## 2. CLASSIFICATION OF SEGMENTATION ALGORITHMS
Image segmentation algorithms can be classified in many ways. Some of the classifications are general whereas others are tailored according to some specific application domain [9]. In this paper we consider two separate classification strategies: first is to classify each algorithm from its usefulness point of view i.e. application centric and second viewpoint focuses on the method of the algorithm itself.

## 2.1 Application Centric Classification

Image segmentation algorithms are designed with respect to the application domain. This do not limit the use of the segmentation technique for other applications, however it implies certain requirements that may be incompatible with other domains. Fig. 1 illustrates four specific aspects that influence the domain in which a segmentation algorithm can be used

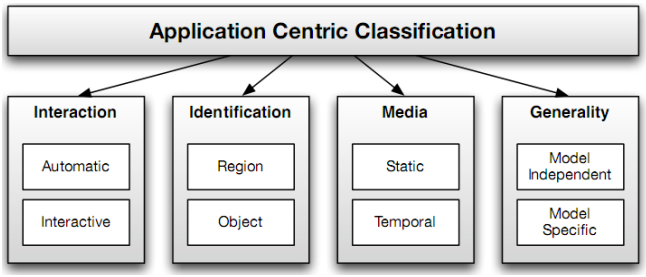


**Fig. 1 Application Centric Classification of Segmentation Algorithms**

### *2.1.1 Interaction*

Based on the amount and granularity of interaction required to perform image segmentation, algorithms can be divided into two categories: automatic and interactive. Automatic image segmentation algorithms require no user interaction to segment the image. This type of segmentation used to partition images into regions enables local feature extraction in many multimedia information retrieval systems e.g. Blobworld [10] and 2007 K-Space TrecVid engine. Automatic segmentation algorithms are effective for applications that require quick, coarse and region-based segmentation. But in applications which require more accurate semantic objects, fully automatic segmentation is impossible. So some high level information is needed to traverse the "semantic gap" between homogeneous regions and perceived objects.

Interactive segmentation algorithms provide a solution by invoking the help of a human operator. Human operator supplies the high level information needed to detect and extract semantic objects through series of interactions. Usually, operators mark areas of the image as object or background, and algorithm updates the segmentation using the new information. User can fine tune the segmentation by repeatedly providing more interactions. This type of segmentation algorithms are used to extract semantic objects from an image quickly and accurately. These can also be classified as semi-supervised segmentation algorithms.

### *2.1.2 Identification*

Segmentation techniques also differ in the type, form and quantity of objects that they identify. Based on what image segmentation algorithms identify, we can divide them into two categories: object-based, and region- based.

Object-based algorithms divide the image into two different parts: object pixels and non-object pixels. Most thresholding techniques [11] can be considered simple object-based segmentation algorithms. Many interactive segmentation algorithms are also object-based.

Region-based algorithms partition the image into an arbitrary number of regions. There is no semantic significance assigned to these regions. The goal is just to create regions that are, in some way, coherent or homogeneous. Majority of automatic segmentation algorithms are region-based. Segmentation algorithms designed for use on natural scenes are region-based as it is very difficult to detect objects without some high level information about the scene. These algorithms do not directly imply what regions is part of the foreground, whereas most semantic objects are composed of several regions in the segmentation

### *2.1.3 Media*

Another factor to decide what segmentation technique to apply is to know if the algorithm is intended to be used on video sequences or static images. Most of the classic segmentation algorithms were originally proposed for static image segmentation such as Watershed segmentation [12] and interactive split and merge algorithms [13].

### *2.1.4 Generality*

Finally, for selecting a segmentation algorithm for an application area, we have to consider the algorithm's generality. Algorithms that are designed for a particular domain are referred as model – specific, and algorithms that can be used in general irrespective of that application domain are called model-independent. So we can say that a model-specific algorithm gives good results in their respective domains, whereas model-independent algorithms can be used to perform segmentation in more applications.

When application domain us restrictive then model-specific algorithms are better choice. For example, in medical image analysis, the kinds of objects that are to be segmented are specific enough for model-specific techniques to perform well: atlas guided segmentation [14], active contours [15] are some examples of such methods. Also, Hough Transform and its derivatives are model specific algorithms are suitable for segmenting regular shapes like line and curves [16], [17]. And when application requires segmentation of more general scenes then model-independent algorithms are used.

## 2.2 Algorithm Centric Classification

Other than categorizing segmentation algorithms on the basis of application domains in which they can be used, we can consider segmentation algorithms in terms of the properties of the segmentation algorithms themselves. This classification of segmentation algorithm may not help in selecting a segmentation algorithm for some application but it is useful in developing and evaluating segmentation algorithms. Fig 2 illustrates the algorithm centric classification based on the general properties of algorithms: how it considers data (*perspective*), the problem that algorithm is trying to solve (*model*), and the level at which it attempts to compute the solution (*scale*)

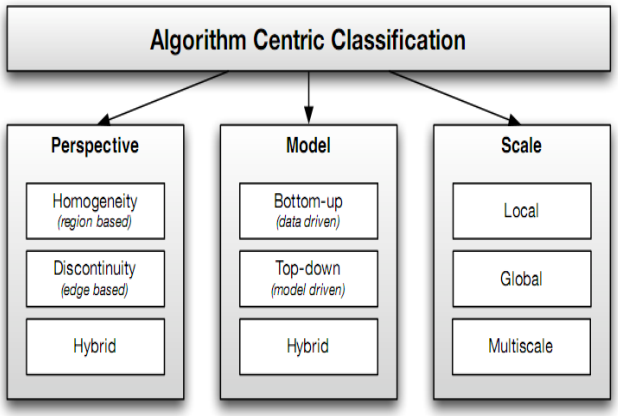


**Fig 2. Algorithm Centric Classification of Segmentation Algorithms**

### *2.2.1 Perspective*

Most of the segmentation algorithms can be either region based, edge-based, or hybrid of these. Region based algorithms attempt to produce coherent regions by clustering together group of pixels based on some homogeneity condition. Edge-based algorithms focus on determining the discontinuities in the image, usually by approximating the first or second order derivatives, and then link together these edge pixels to form closed regions. Hybrid algorithms use both homogeneity and discontinuity information to perform the segmentation. [18] described EDISON system, which is example of a hybrid algorithm. It is also reported that homogeneity and discontinuity plays an important role in low level human and animal vision [19],[20].

### *2.2.2 Model*

The model used to form a segment is related to the algorithm's generality discussed in application centric classification. Bottom-up algorithms are also referred as data-driven algorithms, attempt to infer regions or objects using low-level visual signals, like color, texture etc. so data driven algorithms form the set of general segmentation techniques. Top-down, or model driven algorithms, begin with some assumptions about the nature of the scene, i.e. they have specific model of the objects that are to be segmented, and proceed by attempting to locate and extract these objects. For example face extraction; line extraction etc. [21] classified the segmentation algorithms primarily on basis of model view. They also considered semi-automatic and interactive segmentation algorithms to be model driven where the model is created by using markup provided by the user.

### *2.2.3 Scale*

It is important to consider the level at which algorithms process in formation in the scene. Local algorithms process certain subset of the pixels in the scene at each step. Usually this subset is defined by a central pixel and a prescribed set of neighboring pixels. Examples of local segmentation algorithms include: mean-shift [22], seed region growing [23], statistical region merging [8], region adjacency graphs [24] and recursive shortest spanning tree [2].

Global algorithms, consider an entire image when doing segmentation. This often involves portioning the image into regions while optimizing some predefined criteria. Popular global algorithms are Normalized cuts algorithm [6], the interactive graph cuts algorithm [25] and algorithms that are based on Hough transform [16].

Multi-scale algorithms, generally consider only local features, but do so at several different scales.

## 3. GROUPING CUES

All segmentation techniques require some method to determine which pixels belong to which region. This criteria is called grouping cues. This will help in grouping pixels into regions and then further into objects based on human visual system. To humans, an image is not just a random collection of pixels; it is a meaningful arrangement of regions and objects. Despite of large variations in images, humans can easily interpret them. Human visual grouping was studied extensively by the Gesalt psychologists in early 20$^{th}$ century (27). They identified several factors that lead to human perceptual grouping: similarity, proximity, continuity, symmetry, parallelism, closure and familiarity. These factors are used as guidelines for grouping algorithms in area of computer vision (26). However, the Gesalt principles stated above are descriptive, not explanatory; they do not tell us how or why humans perceive entities in this way. And also the degree of effect of any particular Gesalt principle on our interpretation of scene is difficult to quantify. Such difficulties have lead to researchers focusing their efforts mainly on the proximity and similarity principles, as these can be easily formulated in terms of low level image features.

### 3.1 Low Level Features

In order to perform the perceptual grouping, the Gesalt principles tell us that we should group pixels that are in some way close to each other (proximity), and that are also in some way alike (similarity). The most common way to decide similarity between pixels is by using low level features in image and defining measures between these features. The purpose of low level image features is to encapsulate information about the pixels they describe. The purpose of distance measures is to describe how similar two sets of pixels are, based on the low level features that describe them. Some of these low level features are directly available from image pixels; others require pre-filtering to extract. Most commonly used low level features in image segmentation are: spatial distance, color, edges, texture and geometry [28].

## 4. DIFFERENT SEGMENTATION ALGORITHMS

Based on the above discussion, in this section we aim to categorize the segmentation algorithms as: Automatic Image segmentation algorithms and Interactive image Segmentation algorithms. There are many segmentation algorithms in literature, here we are briefly analyzing two automatic and two interactive segmentation algorithms.

## 4.1 Automatic Segmentation Algorithms

The segmentation algorithms in this category do not require any user interaction. There are many such algorithms, but we are only summarizing the properties of Statistical Region Merging and Normalized Cuts Algorithm and Mean Shift Algorithm. Other automatic segmentation algorithms are region adjacency graphs, watershed transform [12], split and merge [13], recursive shortest path spanning tree algorithm, ratio-cut algorithms etc [28].

Automatic segmentation algorithms are used for applications that require partitioning of an image into homogeneous regions . Other applications may require high level semantic objects. Automatic segmentation algorithms are, unable to extract semantic objects without high level information about the

scene. For some domains, high level information can be provided in form of some prescribed model, but in more general applications, there is no general model that be used by automatic segmentation algorithms to obtain high level information about the scene [28].

The analysis is summarized in the Table 1 as given below.

**Table 1 Analysis of Automatic and Interactive Image Segmenattion Algorithms**

| Type of segmentation | Name of Algorithm | Application Centric | | | | Algorithm Centric | | |
|---|---|---|---|---|---|---|---|---|
| | | Interaction | Identification | Media | Generality | Perspective | Model | Scale |
| Automatic Image Segmentation | Statistical Region Merging | Automatic | Region | Static | Model Independent | Homogeneity | Data Driven | Local |
| | Normailzed Cut Algorithm | Automatic | Region | Static/ Temporal | Model Independent | Homogeneity | Data Driven | Global |
| | Mean Shift Algorithm | Automatic | Region | Static/ Temporal | Model Independent | Homogeneity | Data Driven | Local |
| Interactive Image Segmentation | Seeded Region Growing | Semi-Automatic | Region/Object | Static | Model Independent | Homogeneity | Data Driven | Local |
| | Interactive graph cut algorithm | Semi-Automatic | Object | Static | Model Independent | Homogeneity | Data Driven | Global |
| | Simple Interactive Object Extraction Algorithm | Semi-Automatic | Object | Static | Model Independent | Homogeneity | Data Driven | Global |

## 4.2 Interactive Segmentation Algorithms

Interactive segmentation algorithms overcome the problem associated with automatic segmentation and can extract semantic objects by using the high level information provided by the user. The algorithms use the knowledge provided by user interaction to guide the segmentation. These algorithms provide feedback to the user and allow them to iteratively improve the segmentation. These algorithms can fall in these categories: *thresholding, region growing, classifiers, graph based* and *deformable models*. Here we will summarize three interactive algorithms: seeded region growing, Interactive Graphs Cut Algorithm, Simple Interactive Object Extraction in Table 1.

Algorithms based on active contours and deformable models [15] are popular in medical image segmentation. These are not very effective in natural image segmentation as they are sensitive to initial parameterization. And it is difficult to initialize parameters for broad natural domain. And also these algorithms need interaction in form of object outline which makes refining of segmentation difficult.

## 5. CONCLUSION

In this paper we have focused on reviewing existing image segmentation algorithms and then classified them on the basis of two perspectives: application centric and algorithm centric. That is classification of segmentation algorithms is based on their applicability and algorithmic properties. Then we discussed several grouping cues upon which image segmentation algorithms are based. There are many different segmentation algorithms available, and to select the best one for application require formally evaluating segmentation algorithms. The performance of any segmentation algorithm depends on the application itself. For one application, a segmentation algorithm performs well as it mimics closely human perceptual grouping whereas in another, computational efficiency or stability may be more important.

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