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Implementation and Comparison

of Different Image Segmentation Algorithms

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*Abstract*—For some applications, such as image recognition or compression, we cannot process the whole image directly for the reason that it is inefficient and unpractical. Therefore, several image segmentation algorithms were proposed to segment an image before recognition or compression. Image segmentation is to classify or cluster an image into several parts (regions) according to the feature of image, for example, the pixel value or the frequency response. Up to now, lots of image segmentation algorithms exist and be extensively applied in science and daily life. According to their segmentation method, we can approximately categorize them into region-based segmentation, and edge-base segmentation. In this paper, we survey several popular image segmentation algorithms, discuss their specialties, and show their segmentation results.

*Index Terms*—Image segmentation, Edge-based segmentation, Region-growing segmentation, Watershed algorithm.

# INTRODUCTION

I

n digital signal processing, image segmentation is the process of partitioning a [digital image](http://en.wikipedia.org/wiki/Digital_image) into multiple segments ([sets](http://en.wikipedia.org/wiki/Set_(mathematics)) of [pixels](http://en.wikipedia.org/wiki/Pixel), also known as super pixels). The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics.

The result of image segmentation is a set of segments that collectively cover the entire image, or a set of [contours](http://en.wikipedia.org/wiki/Contour_line) extracted from the image (see [edge detection](http://en.wikipedia.org/wiki/Edge_detection)). Each of the pixels in a region are similar with respect to some characteristic or computed property, such as [color](http://en.wikipedia.org/wiki/Color), [intensity](http://en.wikipedia.org/wiki/Luminous_intensity), or [texture](http://en.wikipedia.org/wiki/Image_texture). Adjacent regions are significantly different with respect to the same characteristics. When applied to a stack of images, typical in [medical imaging](http://en.wikipedia.org/wiki/Medical_imaging), the resulting contours after image segmentation can be used to create 3D reconstructions with the help of interpolation algorithms like [Marching cubes](http://en.wikipedia.org/wiki/Marching_cubes).

In this paper, we detect four images using the edge-based algorithm and region-based algorithm respectively. Besides, we make a comparison of these image segment algorithms and draw a conclusion at last.

# The Theory of segmentation

## Edge-based segmentation

[Edge detection](http://en.wikipedia.org/wiki/Edge_detection) is a well-developed field on its own within image processing. Region boundaries and edges are closely related, since there is often a sharp adjustment in intensity at the region boundaries. Edge detection techniques have therefore been used as the base of another segmentation technique.

The edges identified by edge detection are often disconnected. To segment an object from an image however, one needs closed region boundaries. The desired edges are the boundaries between such objects or spatial-taxons. Spatial-­taxons are information granules, consisting of a crisp pixel region, stationed at abstraction levels within a hierarchical nested scene architecture. They are similar to the Gestalt psychological designation of figure-­ground, but are extended to include foreground, object groups, objects and salient object parts. Edge detection methods can be applied to the spatial-taxon region, in the same manner they would be applied to a silhouette. This method is particularly useful when the disconnected edge is part of an illusory contour.

Segmentation methods can also be applied to edges obtained from edge detectors. Lindeberg and Li developed an integrated method that segments edges into straight and curved edge segments for parts-based object recognition, based on a minimum description length (MDL) criterion that was optimized by a split-and-merge-like method with candidate breakpoints obtained from complementary junction cues to obtain more likely points at which to consider partitions into different segments.

## Region-growing segmentation

[Region-growing](http://en.wikipedia.org/wiki/Region-growing) methods rely mainly on the assumption that the neighboring pixels within one region have similar values. The common procedure is to compare one pixel with its neighbors. If a similarity criterion is satisfied, the pixel can be set to belong to the cluster as one or more of its neighbors. The selection of the similarity criterion is significant and the results are influenced by noise in all instances.

The method of Statistical Region Merging (SRM) starts by building the graph of pixels using 4-connectedness with edges weighted by the absolute value of the intensity difference. Initially each pixel forms a single pixel region. SRM then sorts those edges in a priority queue and decide whether or not to merge the current regions belonging to the edge pixels using a statistical predicate.

One [region-growing](http://en.wikipedia.org/wiki/Region-growing) method is the seeded region growing method. This method takes a set of seeds as input along with the image. The seeds mark each of the objects to be segmented. The regions are iteratively grown by comparison of all unallocated neighboring pixels to the regions. The difference between a pixel's intensity value and the region's mean, \delta, is used as a measure of similarity. The pixel with the smallest difference measured in this way is assigned to the respective region. This process continues until all pixels are assigned to a region. Because seeded region growing requires seeds as additional input, the segmentation results are dependent on the choice of seeds, and noise in the image can cause the seeds to be poorly placed.

Another [region-growing](http://en.wikipedia.org/wiki/Region-growing) method is the unseeded region growing method. It is a modified algorithm that does not require explicit seeds. It starts with a single region A_1—the pixel chosen here does not markedly influence the final segmentation. At each iteration it considers the neighboring pixels in the same way as seeded region growing. It differs from seeded region growing in that if the minimum \delta is less than a predefined threshold T then it is added to the respective region A_j. If not, then the pixel is considered different from all current regions A_i and a new region A_{n+1} is created with this pixel.

One variant of this technique, proposed by [Haralick](http://en.wikipedia.org/wiki/Haralick" \o "Haralick) and Shapiro, is based on pixel [intensities](http://en.wikipedia.org/wiki/Brightness). The [mean](http://en.wikipedia.org/wiki/Arithmetic_mean) and [scatter](http://en.wikipedia.org/wiki/Scatter) of the region and the intensity of the candidate pixel are used to compute a test statistic. If the test statistic is sufficiently small, the pixel is added to the region, and the region’s mean and scatter are recomputed. Otherwise, the pixel is rejected, and is used to form a new region.

A special region-growing method is called \lambda-connected segmentation (see also [lambda-connectedness](http://en.wikipedia.org/wiki/Lambda-connectedness)). It is based on pixel [intensities](http://en.wikipedia.org/wiki/Brightness) and neighborhood-linking paths. A degree of connectivity (connectedness) is calculated based on a path that is formed by pixels. For a certain value of \lambda, two pixels are called \lambda-connected if there is a path linking those two pixels and the connectedness of this path is at least \lambda. \lambda-connectedness is an equivalence relation.

Split and merge segmentation is based on a [quad tree](http://en.wikipedia.org/wiki/Quadtree) partition of an image. It is sometimes called quad tree segmentation.

This method starts at the root of the tree that represents the whole image. If it is found non-uniform (not homogeneous), then it is split into four son squares (the splitting process), and so on. If, in contrast, four son squares are homogeneous, they are merged as several connected components (the merging process). The node in the tree is a segmented node. This process continues recursively until no further splits or merges are possible. When a special data structure is involved in the implementation of the algorithm of the method, its time complexity can reach O(n\log n), an optimal algorithm of the method.

## Watershed segmentation

The [watershed transformation](http://en.wikipedia.org/wiki/Watershed_(algorithm)) considers the gradient magnitude of an image as a topographic surface. Pixels having the highest gradient magnitude intensities (GMIs) correspond to watershed lines, which represent the region boundaries. Water placed on any pixel enclosed by a common watershed line flows downhill to a common local intensity minimum (LIM). Pixels draining to a common minimum form a catch basin, which represents a segment.

The main goal of watershed segmentation algorithm is to find the “watershed lines” in an image in order to separate the distinct regions. To imagine the pixel values of an image is a 3D topographic chart, where x and y denote the coordinate of plane, and z denotes the pixel value. The algorithm starts to pour water in the topographic chart from the lowest basin to the highest peak. In the process, we may detect some peaks disjoined the catchment basins, called as “dam”. The diagram shows in Fig. 1.

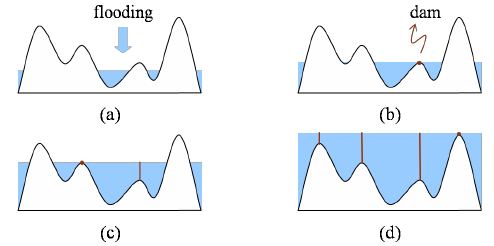


Fig.1. The concept of watershed algorithm.

Then, we get the result of 2D DFT. The result of logarithmic magnitude of 2D DFT coefficients (Fig.1) shows that the image contains components of all frequencies, but that their magnitude gets smaller for higher frequencies. Hence, low frequencies contain more image information than the higher ones.

The transformed image in Fourier domain also tells us that there are two dominating directions in the Fourier image, one passing vertically and one horizontally through the center. The phase image does not yield much new information about the structure of the spatial domain image. The result of logarithmic magnitude of 2D DFT coefficients shows that the image contains components of all frequencies, but that their magnitude gets smaller for higher frequencies. Hence, low frequencies contain more image information than the higher ones. The transformed image in Fourier domain also tells us that there are two dominating directions in the Fourier image, one passing vertically and one horizontally through the center. The phase image does not yield much new information about the structure of the spatial domain image.

# experimental results and analysis

## Results of edge-based segmentation

Depending on the theory applied before, we have implemented the edge-based segmentation algorithm on the boat image using Matlab. As we can see from the Fig.2. the first image is the original image named brain. Then, we try to applied different operators on it and observe different results. From (b) to (f), we use [Laplacian](http://www.baidu.com/link?url=VvchLqughUDbMrnfeVX4sxylD01lN9X8JiyRDGovAMdZukXirlme9L19Uy5gpopcTJHeKTsXnsFptCxhmhVxUK) operator, Roberts operator, Sobel operator, Prewitt operator and Canny operator according to priority. Overall, it seems that Laplacian does the better for some features. Considering other operators, it is hard to say which operator is better because each operator has some unique advantages and unavoidable disadvantages.

|  |  |
| --- | --- |
| (a) | (b) |
| (c) | (d) |
| (e) | (f) |

Fig. 2. Edge-based segmentation experiment. (a)original image (b) [Laplacian](http://www.baidu.com/link?url=VvchLqughUDbMrnfeVX4sxylD01lN9X8JiyRDGovAMdZukXirlme9L19Uy5gpopcTJHeKTsXnsFptCxhmhVxUK) operator, (c) Roberts operator, (d) Sobel operator, (e) Prewitt operator, (f) Canny operator.

## Results of region growing segmentation

After the implementation and analysis of edge-based algorithm, we have implemented the region growing segmentation algorithm on this part. We show the segmentation result of boat image in Fig.3. as follows. Firstly, we chose a original image (a) and three points as seed on the original image. Then, we applied region growing algorithm to it and observe the result as (b). Besides, we tried to change the location of seed and got some different results as (c) and (d). With changes of location of seed, (a) and (b) shows the result of seedx=[63,10,80], (c) and (b)shows the result of seedx=[63,150,80], the results would differ.

|  |  |
| --- | --- |
| (a) | (b) |
| (c) | (d) |

Fig. 3. Region growing segmentation algorithm.

## Results of watershed segmentation

We show the segmentation result of the watershed algorithm in Fig. 4. From the results, we can fine the advantages and disadvantages of the watershed algorithm as follows. Advantages: the boundaries of each region are continuous. Disadvantages: the segmentation result has over-segmentation problem, shown in , the algorithm is time-consuming.

|  |  |
| --- | --- |
| (a) | (b) |
| (c) | (d) |

Fig. 4. Watershed segmentation algorithm

# Comparison

Here we compare the difference between different image segmentation algorithms noted before. The results are shown as follws.

As we can see from the Fig.5, the first image is the origin image, named hat, which our experiments are based on. Fig.5(b) shows the result of edge-based algorithm, concretely, Laplacian operator. Then we applied region growing algorithm to the original image and get the result as (c). In the end, we use the watershed algorithm and result is shown on (d).

|  |  |
| --- | --- |
| (a) | (b) |
| (c) | (d) |

Fig.5. Comparison (a) is the original, (b) is the result of edge-based algorithm, (c) shows the application of region growing algorithm and (d) shows the result of watershed algorithm.

In edge-based segmentation algorithm, all pixels are initially labelled as either being on an edge or not, then non-edge pixels which form connected regions are allocated to the same category.

Region-based segmentation algorithms act by grouping neighbouring pixels which have similar values and splitting groups of pixels which are heterogeneous in value.

# Conclusion

In this paper we have implemented different image segmentation algorithms, and performed a comparison. Segmentation is the allocation of every pixel in an image to one of a number of categories, which correspond to objects or parts of objects. Commonly, pixels in a single category should: have similar pixel values, form a connected region in the image, be dissimilar to neighbouring pixels in other categories. Segmentation algorithms may either be applied to the original images, or after the application of transformations and filters.

Three general approaches to segmentation are: edge-based algorithm, region growing algorithm and watershed algorithm. It is hard to say which is better. Concreting analysis of concrete conditions is crucial as we solving the problem.

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1. Manuscript received XXX; revised XXX; accepted XXX. This work just is the project assigned by the teacher(Digital Image Processing).

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