Chapter 7
Graph Based Segmentation of Digital Images

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ABSTRACT

Image Segmentation is the process of dividing an image into semantically relevant regions. The problem is still an active area due to wide applications in object detection and recognition, image retrieval, image classification, et cetera. The problem is challenging due to its subjective nature. Many researchers addressed this problem by exploring graph theoretic principles. The key idea is the transformation of segmentation problem into graph partitioning problem by representing the image as a graph. The aim of this chapter is to study various graph based segmentation algorithms.

INTRODUCTION

Image processing is an active locale of research in computer science. Its growth has been accelerated by technological advances in digital imaging, computer processors and mass storage devices. The traditional analog oriented hardware has been migrated towards digital systems due to their flexibility and affordability. The central themes of image processing are the study of images for better visualization and understanding and also to perform further analysis.

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Digital image processing is concerned primarily with extracting useful information from images. Ideally, this is done by computers, with little or no human intervention. Image processing problems are categorized into three levels - low, medium and high. The techniques at the lowest level deal directly with the raw, possibly noisy pixel values, with operations like pre-processing, enhancement, noise removal etc. In the medium level, the algorithms utilize low level results for further means, such as segmentation, edge detection and linking. At the highest level, the methods attempt to extract semantic meaning from the information provided by the lower levels like iris recognition, fingerprint matching etc.

Image Segmentation is related to perceptual organization. The Gestalt theory, founded by (Max Wertheimer, 1938) identified a set of grouping laws under ideal simplistic settings for artificial stimuli. Elements are structured into groups sharing a common feature like intensity, color or any other statistical feature.

This chapter is concerned with the study of segmentation of digital images using graph theoretical approaches.

SEGMENTATION PROBLEM

Image segmentation is a part of the classification or recognition problem. Segmenting an image is defined as the process to partition the image pixels into dissimilar regions. The same approach is called clustering if the given data is taken from any other source other than an image. Mathematically it is defined in Gonzalez et.al (2008) as follows.

Let R represent the entire spatial region occupied by an image. The image segmentation process is viewed as a process that partitions R into p sub-regions, $R_1, R_2, \ldots, R_p$ such that

$$U_{i=1}^{p} R_i = R$$

Ri is a connected set, i=1,2,…,p

$$R_i \bigcap R_j = \varnothing \, \forall \, i, j \, and \, i \neq j$$

$$Q\left(R_i\right) = TRUE \, for \, i = 1, 2, \ldots, p$$

$$Q\left(R_i \bigcup R_j\right) = FALSE \, for \, any \, adjacent \, regions \, R_i \, and \, R_j, \; i \neq j$$

Here, Q(x) is a logical predicate defined over the points in set R_i.

The basic idea is that a human being can perceive this world through eyes in terms of image or scenery. At any instant, on perceiving the image, some grouping is done by human based on the objects present in his / her visualization. Similar task should be accomplished by an algorithm that perceives the input imagery.

MOTIVATION

In machine vision, image processing is usually a costly operation that should nevertheless perform in real time. An efficient segmentation algorithm can help to reduce the amount of visual information that needs to be processed. Human brain is capable of simultaneously analyzing and processing many tasks and this aid in segmenting or dividing the visual image into related objects. The same task over an image by an algorithm is extremely difficult. Image segmentation, as a computational problem, is interesting for at least three reasons: First, there are large numbers of potential applications. Second, image segmentation is interesting because it serves as a test bed for ideas from other fields like machine learning, pattern recognition, physics and engineering. For instance, in its simplest form, image segmentation can be regarded as a clustering problem. Clustering algorithms can often be used in an image segmentation framework, and, conversely, algorithms developed for image processing can be very successful in clustering problems as well. Finally, image segmentation is domain specific. This adds to the challenge because the algorithms which are highly successful for a particular theme may not work properly for other domains. In other words, no common algorithm exists for all types of images.

Segmentation methods can be broadly classified into parametric and nonparametric approaches. In the parametric methods the basic idea is to fit the histogram with a sum of Gaussian distributions, then find the optimal thresholds at the intersections of these Gaussians. However, when the histogram is unimodal these methods are not able to provide a threshold, and if the