Image Segmentation Methods

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INTRODUCTION

Pictures, when used in a computational environment, are known as digital images, representing the two-dimensional visual information. They are stored in binary files as bitmap or vector images. The former are represented bit-by-bit and the latter by geometric objects such as lines, dot, curves and polygons. Image segmentation is a fundamental step in modern computer vision systems and its goal is to produce a more simple and meaningful representation of the image making it easier to analyze. Image segmentation is a subcategory of image processing of bitmap digital images. Basically, it divides a given image in two parts: the object(s) of interest and the background. Image segmentation is typically used to locate objects and boundaries in images and its applicability extends to other methods such as classification, feature extraction and pattern recognition. Most methods are based on histogram analysis, edge detection and region-growing. Recently, other approaches came up such as segmentation by graph partition, using genetic algorithms (GA) and genetic programming (GP). This article presents an overview of this area, starting with a taxonomy of the methods, followed by a discussion of the most relevant ones.

BACKGROUND

Image Segmentation

In bitmap graphics (not in vector graphics) segmentation is a pre-processing step in computer vision where images are partitioned into several distinct regions formed by a set of pixels (picture element). Such regions are further labeled as foreground (objects of interest) or background, based on the common properties the pixels of a region must share (such as color, intensity, texture, etc).

Several image segmentation methods were proposed in the literature. However, a single method may not be efficient for a specific image class, and a combination of them is necessary to solve interesting real-world problems. The main methods for image segmentation are based on histogram analysis, edge detection and segmentation by regions.

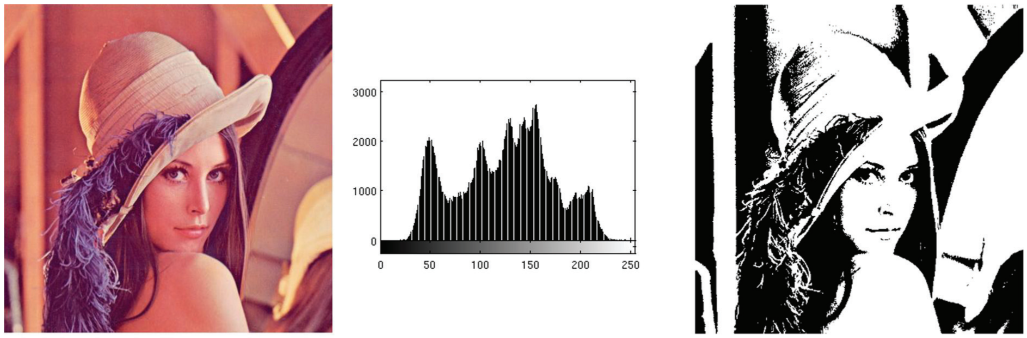
Histogram Analysis

A histogram is a graphical representation in which a data set is grouped into uniform classes such that the horizontal axis represents the classes and, the vertical axis, the frequencies in which the values of these classes are present in the data set. Based on the central tendency or histogram variation it is possible to determine the cutoff point that will be used as threshold in these segmentation process. In this approach classes with high and low frequency are identified where a class with low frequency between two high frequency classes usually represents the best cutoff point to image threshold. An example of histogram analysis is presented in Figure 1 (b) where classes with high and low frequencies can be seen.

An efficient approach for image segmentation based on histogram analysis is the Otsu method (Otsu, 1979). This method performs several iterations analyzing all possible thresholds to look for the best threshold T that presents the highest inter-class variance. This method assumes that the image to be segmented will be classified in two classes, object and background, and threshold point will be determined by the pixel intensity value that represents the minimum intra-class variance. This threshold is exhaustively searched and can be defined as a weighted sum of the variances of the two classes, as shown in Equation 1:

DOI: 10.4018/978-1-4666-5888-2.ch588

Figure 1. (a) Original color image; (b) Original histogram image; (c) Segmented image using Otsu approach



(a) (b) (c)

$$\sigma^2_{intra} = W_a \sigma^2_a + W_b \sigma^2_b \quad (1)$$

where σ represents the variance of these classes and weights W_i represents the occurrence probability of each class being separated by a threshold T. Figure 1 (a) shows the original color image and Figure 1 (c) shows image segmented by Otsu approach.

Edge Detection

Edge detectors are common methods to find discontinuities in gray level images. An edge is a set of pixels of similar intensity level connected by adjacent points. We can find out edges by estimating the gradient intensity. Edges in images can be divided in two distinct categories: intensity edges and texture edges. In the first, the edges arise from abrupt changes in the image pattern and, in the second case, edges are detected by the limits of textures in regions invariant to illumination changes (Tan, Gelfand, & Delp, 1989).

The Roberts edges operator (Fu & Mui, 1981) performs a simple 2-D spatial gradient analysis in digital images and emphasizes regions with high spatial gradient that can be edges. This method is a fast and simple convolution-based operator and, usually, the input of the method is a grayscale. Basically, a convolution mask is a set of weightings applied to pixel values in order to create a new effect. They can be applied to the input image to produce the absolute magnitude of gradient and the orientation. If applied separately, it is possible to measure the gradient component in each orientation. The gradient magnitude is given by Equation 2 and an example of image segmentation using Roberts edge operator is shown in Figure 2 (a):

$$|G| = |G_x| + |G_y| \quad (2)$$

Figure 2. (a) Segmented image using Roberts's method; (b) Segmented Image using Sobel's method; (c) Segmented image using Canny's operator

(a) (b) (c)

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