New Advancements in Image Segmentation for CBIR

Yu-Jin Zhang

Tsinghua University, Beijing, China

INTRODUCTION

The process of segmenting images is one of the most critical ones in automatic image analysis whose goal can be regarded as to find what objects are presented in images (Pavlidis, 1988). Image segmentation consists of subdividing an image into its constituent parts and extracting these parts of interest (objects). A large number of segmentation algorithms have been developed since the middle of 1960's (see survey papers and books, for example, Bovik, 2000; Fu & Mui, 1981; Lucchese & Mitra, 2001; Medioni, Lee, & Tang, 2000; Pal & Pal, 1993; Zhang, 2001), and this number continually increases from year to year in a fast rate. This number had attended, 10 years ago, the order of thousands (Zhang & Gerbrands, 1994). However, none of the proposed segmentation algorithms is generally applicable to all images, and different algorithms are not equally suitable for a particular application. Though several thousands of algorithms have been proposed, improvements for existing algorithms and developments for treating new applications are still going on.

Along with the progress of content-based image retrieval (CBIR) that searches images from a collection according to the content of images, especially with the object-based techniques, image segmentation has been involved more and more in this new research domain. By separating an image into different components and extracting the interest objects, more semantic meanings could be mined out from the image. Thus, the human intention could be fully represented and integrated into the search process. Due to the specific requirements and particular constrains of CBIR, not only have many common segmentation techniques proposed before the start of CBIR research in 1992 have been revised, but also various techniques specialized to the tasks of CBIR have been developed.

The remainder of this article is organized as follows: in the *BACKGROUND* section, image segmentation techniques are briefly summarized; and the specific requirements of CBIR to image segmentation are stated. In *MAIN THRUST*, a general trend for developing image segmentation techniques to fit the particular requirements of CBIR are discussed; some useful techniques for segmentation in the context of CBIR, such as meaningful region extractions and two-level segmentation are presented. In *FU-TURE TRENDS*, some potential directions for further research are indicated. In *CONCLUSION*, several final remarks are given.

BACKGROUND

Classification of Image Segmentation Techniques

A formal mathematical-oriented definition for image segmentation can be found in Fu and Mui (1981). Generally speaking, it defines image segmentation as a process of treating every pixel in images to form non-overlap regions, each of which has certain properties different from that of others.

As many techniques for image segmentation have been proposed in the literature, the classification of segmentation algorithms becomes critical. Algorithm classification should be performed according to some suitable classification criteria; otherwise, the classification schemes might be non-consistent and/or non-complete (Fu & Mui, 1981; Pal & Pal, 1993).

Considering the classification of segmentation algorithms as a partition of a set (of algorithms) into subsets, an appropriate classification scheme should satisfy the following four conditions (Zhang, 1997; Gonzalez & Woods, 2002):

(1) Every considered algorithm must be classified into one subset.
(2) All subsets together can include all algorithms (form the whole set).
(3) Different algorithms in the same subset should have some common properties.
(4) The algorithms in different subsets should have certain distinguishable properties.

Two criteria commonly used for the classification of segmentation algorithms are based on two pairs of complementary attributes:

(1) Homogeneous property: either discontinual (inter-regions, at boundaries) or continual (intra-region);

(2)   Processing strategy: either sequential (step-by-step) or parallel (simultaneous and independent).

Combining these two criteria, a classification scheme can distinguish the following four groups of segmentation algorithms (Zhang, 2001):

(1)   Boundary-based sequential algorithms;
(2)   Boundary-based parallel algorithms;
(3)   Region-based sequential algorithms;
(4)   Region-based parallel algorithms.

Recently, many new segmentation algorithms based on different theories, such as mathematical morphology, pattern recognition principle, neuron network, information theory, fuzzy logic, wavelet transform, genetic algorithms, and so forth, are proposed (Zhang 2001). All these algorithms can still be classified according to the above classification scheme.

In the context of image analysis aiming at automatically obtaining measurement data from objects, the most important criteria for judging the performance of segmentation algorithms are related to the accuracy of segmentation results, though some other criteria, such as processing complexity and efficiency as well as segmentation resolution of algorithms, are also considered (Zhang, 1996). From the accuracy point of view, the algorithms based on boundary representation and sequential strategy are often more powerful (especially for noisy images), according to their natures, than other algorithms.

Particularity of Image Segmentation in CBIR

Design of segmentation techniques for CBIR counts several new challenges. Two of them are indicated here.

In contrast to many applications of image analysis, which aim at obtaining objective measurements over objects in the images, CBIR is a somehow subjective process (Zhang, 2003). Instead of deriving accurate measures of object properties for further identification or classification, the primary concerns in CBIR are to separate required regions and to obtain more information related to the semantic of these regions.

From other side, typical image analysis applications are normally limited to particular domains, some *a priori* knowledge about the scene geometry, the sensor characteristics, lighting conditions, noise statistics, number and form of objects, and so forth, are available. Taking into consideration such kinds of information, the results of segmentation could be improved. While in CBIR using a generic database, none of these factors can be controlled; segmentation algorithms could not be specialized by taking into account this information.

Due to these particular aspects, the development of image segmentation techniques for CBIR should be guided by the purpose of segmentation in CBIR applications.

MAIN THRUST

General Ideas

With the progress in segmentation techniques, people have realized that a precise segmentation of objects in many cases is still beyond the capability of current computer techniques (Zhang, 2001). On the other hand, compared to some image analysis tasks that aim at obtaining accurate measurements from the segmented objects, the requirement for precise segmentation of objects can be somehow relaxed in the context of CBIR. As discussed previously, image retrieval is a subject-oriented process in which the precise object measurement might not be the must. In particular, for object-based image retrieval, the main purpose of segmentation here is for identifying the objects.

Several techniques taken into consideration of these particularities are proposed; some typical examples are discussed in the following.

Taking the homogeneous regions in images as the primitives (the "atomic" structures) and assuming these regions do not necessarily cover the whole images, an algorithm called perceptual region growing (PRG) has been proposed (Siebert, 1998). This algorithm combines region growing, edge detection, and perceptual organization principles together for a domain independent segmentation. The main stages of PRG consist of the following:

(1)   Identify the seed pixels of each region from images;
(2)   Merge adjacent pixels that have similar intensity values to these regions;
(3)   Compute the gradient map of images and try to form closed boundaries with high gradient pixels;
(4)   If a boundary is apparently formed, continuously growing its enclosed region to the limit of boundary.

Presuming that regions in images should integrate enough intrinsic variability to provide a better characterization of regions, an algorithm based on coarse region detection and fine description is suggested (Fauqueur & Boujemaa, 2002). The coarse determination of regions can alleviate the problems caused by over-segmentation that produces homogeneous and small regions, such as: it is hard to differentiate homogeneous regions; it is rarely that a small region to be visually salient in a scene. Since regions are detected coarsely and these regions should be more homogeneous than the whole images, finely de-

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