Algorithm Researcher's Approaches to Image Related Problems

Tetsuo Asano (JAIST, Japan, t-asano@jaist.ac.jp)

In this talk I will talk about my previous achievements for image related problems. Main topics are the followings:

(1) Thresholding of an intensity image into a binary image.

(2) Region segmentation

(3) Contour representation of an image

(4) Image Retrieval

(5) Digital Halftoning

Thresholding of an intensity image into a binary image

It is one of the most fundamental operations to produce a binary image from a given intensity image using some appropriate threshold. There are a number of algorithms for the purpose, one of them based on the discriminant analysis proposed by Ohtsu long time ago can guarantee optimality of results in the sense of maximizing the inter-cluster distance between two classes corresponding to white and black pixels. I combined this with distance transform which is an algorithm for calculating for each white pixel the distance to its nearest black pixel. This algorithm has been applied to finger-print identifications.

Region segmentation

Given an intensity image, we are sometimes required to extract a region for an object in the image. If we do not take any knowledge about the object, only information available for segmentation may be average intensity level and smoothness of the boundary. So, it is reasonable to define an optimal region to be extracted by such a region with smooth enough boundary that maximizes the difference between average intensity levels in the object and background regions. Unfortunately, the problem is proved to be NP-hard to find such an optimal region. However, if we have another constraint that the object region is connected and x-monotone (or y-monotone), then polynomial-time algorithm exists. Algorithmic paradigms such as dynamic programming, prune-and-search, fast matrix search, and parametric search contribute to improving the computational complexity of the algorithm.

Contour representation of an image

The most widely accepted representation of an image is the matrix representation in which each element has numerical information such as a color or a gray level. However, as long as such representation is used, it is not so easy to have operations based on global information. This paper proposes an alternative representation of an image called "contour representation." For each gray level i we compute boundaries of connected regions of pixels with gray levels greater than or equal to i. It is easy to reconstruct an original image from those boundaries. Representation of an image as a collection of those boundary lines (contour lines) associated with gray levels is the contour representation of an image. We first give an output-sensitive algorithm for computing all those contour lines and a compact way of such representation. Then, an image can be dealt with as a set of geometric objects. This leads to several advantageous features such as improving resolution or restoration of flaw regions, which cannot be acomplished in conventional pixel-based approaches.

Image Retrieval

Content-based image retrieval is to find an image that is most similar to a query image in a database of many images. Difficulty is how to define similarity between two images. One promising similarity measure is to compute the earth-movers distance after computing color signatures of those images. Given a color image, we can compute frequencies of colors. Color signature of an image consists of dominant colors. Then, we are required to find a minimum cost to moving the weights of the individual points of the source signature to those of the destination signature. An important advantage of this method is that it can be applied even if the two images have different sizes of color signatures. Unfortunately, two images which look completely different sometimes have very similar color signatures. To resolve this problem we have introduced the idea of contour representations of images. That is, following several representative contour lines, we compute histogram of directions of those contour lines. Combining this directional information with color signature lead to better performance.

Digital Halftoning

Digital halftoning is an important technique to convert an image having several bits for brightness levels into a binary image consisting of black and white dots which looks similar to an input image. The similarity between two images is measured by the total sum of differences in the weighted sums of brightness levels of pixels in a neighborhood surrounding each pixel. Then, the problem of producing an optimal halftoned image is a combinatorial optimization problem to find a binary image minimizing the measure for a given multiple-level image. Despite a negative result that it is NP-complete even for a simple neighborhood consisting of 2×2 pixels, we can rely on approximation algorithms mainly based on network flow algorithms.

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