Image Segmentation

Introduction

The growing need for automated image analysis and interpretation in a wide range of applications necessitates the development of *segmentation* algorithms. Segmentation involves partitioning an image into a set of homogeneous and meaningful regions, such that the pixels in each partitioned region possess an identical set of properties or attributes. These sets of properties of the image may include gray levels, contrast, spectral values, or textural properties. The result of segmentation is a number of homogeneous regions, each having an unique label. An image is thus defined by a set of regions that are connected and nonoverlapping, so that each pixel in the image acquires a unique region label that indicates the region it belongs to. The set of objects of interest in an image, which are segmented, undergoes subsequent processing, such as object classification and scene description. A complete segmentation of an image R involves identification of a finite set of regions $\langle R_1, R_2, R_3, \cdots, R_N \rangle$ such that:

1. $R = R_1 \cup R_2 \cup \cdots R_N.$
2. $R_i \cap R_j = \Phi, \forall i \neq j.$
3. $P(R_i) = \text{True}, \forall\ i$
4. $P(R_i \cup R_j) = \text{False},\ i \neq j$

There may exist a number of possible partitions, but the selection of an appropriate set of regions depends on the choice of the property P association in the region [4]. In addition, connectivity among the pixels in a region need to be considered. Segmentation algorithms are based on one of the two basic properties of gray-level values-discontinuity and similarity among the pixels. In the first category of algorithms, we partition an image based on abrupt changes in gray level. The principal areas of interest within this category are the detection of lines and edges in an image. Thus if we can extract the edges in an image and link them, then the region is described by the edge contour that contains it. We may view the process of segmentation from another perspective. From this point of view, the connected set of pixels having more or less the same homogeneous intensity form the regions. Thus the pixels inside the regions describe the region and the process of segmentation involves partitioning the entire scene in a finite number of regions. The principal approaches in the second category are based on the similarity among the pixels within a region. While segmenting an image, various local properties of the pixels are utilized. The well-established segmentation techniques are:

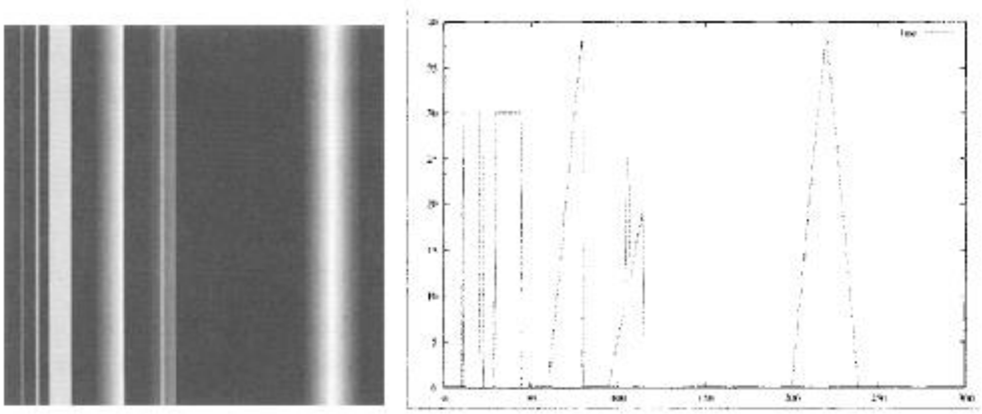
- Histogram-based thresholding
- Region growing
- region splitting and merging

- Clustering/Classification
- Graph theoretic approach
- Rule-based or knowledge-driven approach

This lecture discusses the issues associated with segmentation of an image. We present some of the basic algorithms of image segmentation, starting with the discussions on edge detection process

EDGE, LINE, AND POINT DETECTION

Edge detection: Edges, lines, and points carry a lot of information about the various regions in the image. These features are usually termed **as** local features, since they are extracted from the local property alone. Though the edges and lines are both detected from the abrupt change in the gray level, yet there is an important difference between the two. An edge essentially demarcates between two distinctly different regions, which means that an edge is the border between two different regions. **A** line, on the other hand, may be embedded inside a single uniformly homogeneous region. For example, a thin line may run between two plots of agricultural land, bearing the same vegetation. A point is embedded inside a uniformly homogeneous region and its gray value is different from the average gray value of the region in which it is embedded. This is analogous to a spike. The changes in the gray levels in case of a perfect step edge, line, ramp edge are shown in the form of an edge profile in following figure. The diverse forms and nature of ideal edges and lines, such as step edge, ramp edge, line, step line, are shown in following figure.



Edge profile of one row of a synthetic image.

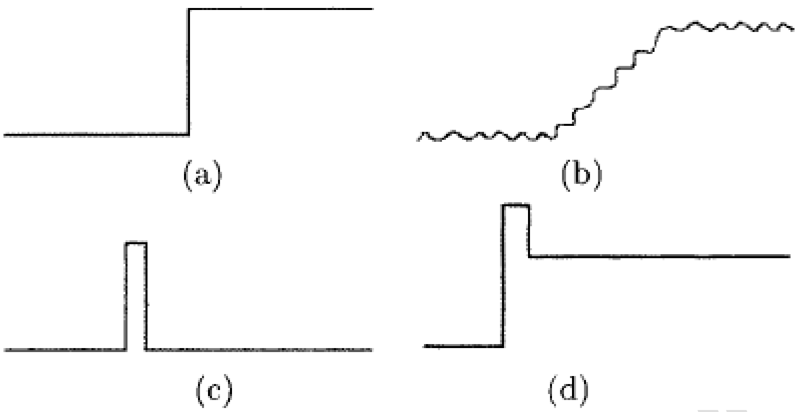


Fig. : different types of edges (a) step, (b) ramp, ***(c)*** line, (d) step-line.

The *edge detection* operation is essentially an operation to detect significant local changes in the intensity level in an image. The change in intensity level is measured by the gradient of the image. Since an image *f(x,y)* is a two-dimensional function, its gradient is a vector

$$\begin{bmatrix} G_x \\ \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{df}{dx} \\ \\ \frac{df}{dy} \end{bmatrix}$$

The magnitude of the gradient may be computed in several ways

$$\left.\begin{aligned} G[f(x,y)] &= \sqrt{G_x^2 + G_y^2} \\ G[f(x,y)] &= |G_x| + |G_y| \\ G[f(x,y)] &= max\,\{|G_x|, |G_y|\} \end{aligned}\right\} \qquad \ldots\ldots(1)$$

The direction of the gradient is :

$$\theta(x,y) = \tan^{-1}(G_y/G_x) \qquad \ldots\ldots(2)$$

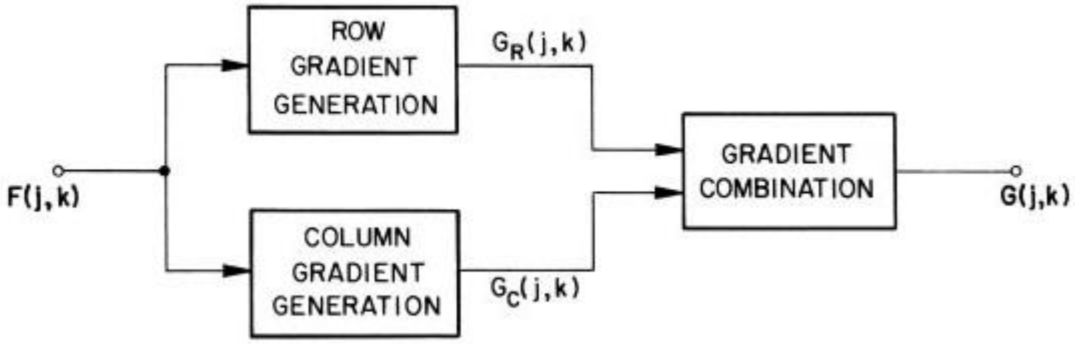
where the angle θ is measured with respect to the X-axis.

Gradient operators compute the change in gray level intensities and also the direction in which the change occurs. This is calculated by the difference in values of the neighboring pixels, i.e, the derivatives along the X-axis and Y-axis. In a two-dimensional image the gradients are approximated by

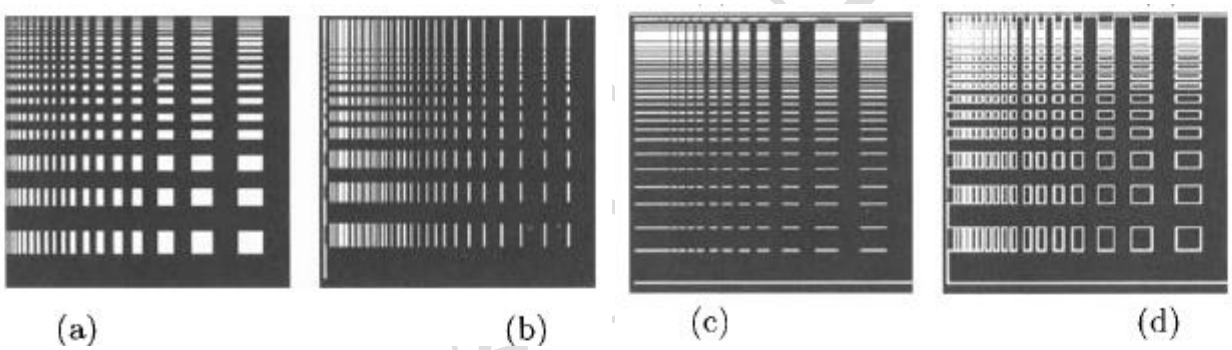
$$G_x = f(i+1,j) - f(i,j)$$

and

$$G_y = f(i,j+1) - f(i,j)$$



Gradient operators require two masks, one to obtain the X-direction gradient and the other to obtain the Y-direction gradient. These two gradients are combined to obtain a vector quantity whose magnitude represents the strength of the edge gradient at a point in the image and whose angle represents the gradient angle. The following figure shows the gradient images of a checker board image along horizontal, vertical directions, and also along both the directions.



(a) Input image, (b) vertical edges, (c) horizontal edges, (d) edge image along both directions.

Alternative approach to computation of edge gradients involves convolving the image with a set of edge templates, chosen in say eight equispaced directions- east, northeast, north, northwest, west, southwest, south, and southeast. The image is convolved with each of these gradient templates. Each template responds to the edges in a particular direction.

Ideal edge detection process

An ideal edge detector is required to detect an edge point precisely in the sense that a true edge point in an image should not be missed, while a false, nonexistent edge point should not be erroneously detected. These two requirements often conflict with each other.

The decision regarding the existence of an edge point is based on a threshold. Thus if the magnitude of the gradient is greater than a threshold, then we infer that an edge point exists at that point, else there is no edge point. If the selected threshold is large, then there is a possibility that true edge points may be undetected, while if the threshold is low, many noisy points may be falsely detected as edge points. The goal of an ideal edge detector is to choose the threshold appropriately.

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