10.1 Introduction

Image segmentation: partition of image into set of nonoverlapping regions

Image segmentation purpose: to decompose image into meaningful parts to application

Image segmentation based on valleys in gray level histogram into 4 regions

--- V. S. Nalwa, *A Guided Tour of Computer Vision*, Fig. 3.20

Rules for general segmentation procedures

1. Region uniform, homogeneous w.r.t. characteristic e.g. gray level, texture
2. Region interiors simple and without many small holes
3. Adjacent regions with significantly different values on characteristic
4. Boundaries simple, not ragged, spatially accurate

Clustering: process of partitioning set of pattern vectors into clusters

Set of points in Euclidean measurement space separated into 3 clusters

--- Fig. 10.2

No full theory of clustering

No full theory of image segmentation

Image segmentation techniques: ad hoc, different in emphasis and compromise

10.2 Measurement-Space-Guided Spatial Clustering

The technique of measurement-space-guided spatial clustering for image segmentation uses the measurement-space-clustering process to define a partition in measurement space.

Histogram mode seeking: a measurement-space-clustering process

Histogram mode seeking: homogeneous objects as clusters in histogram

Histogram mode seeking: one pass, the least computation time

Enlarged image of a polished mineral ore section

--- Fig. 10.3

3 nonoverlapping modes: black holes, pyrochlovite, pyrite

--- Fig. 10.4

2 valleys in histogram is a virtually perfect (meaningful) segmentation

--- Fig. 10.5

Example image not ideal for measurement-space-clustering image segmentation

--- Fig. 10.6

Histogram with three modes and two valleys

--- Fig. 10.7

Undesirable: many border regions show up as dark segments

--- Fig. 10.8

Segmentation into homogeneous regions: not necessarily good solution
diagram of an F/-/-/5 bulkhead

image of a section of the F-15 bulkhead

histogram of the image

five clusters: bad spatial continuation, boundaries noisy and busy

three clusters: less boundary noise, but much less detail

recursive histogram-directed spatial clustering

applied to the bulkhead image

performing morphological opening with 3 x 3 square structuring element

tiny regions removed, but several long, thin regions lost

a color image

recursive histogram-directed spatial clustering using R, G, B bands and other

---Garfield 17:10-----

10.2.1 Thresholding

Kohler defines the set $E(T)$ of edges detected by a threshold $T$ to be the set of all pairs of neighboring pixels one of whose gray level intensities is less than or equal to $T$ and one of whose gray level intensities is greater than $T$

$$E(T) = \{(i, j), (k, l)\}$$

1. pixels $(i, j)$ and $(k, l)$ are neighbors
2. $\min\{I(i, j), I(k, l)\} \leq T < \max\{I(i, j), I(k, l)\}$

The total contrast $C(T)$ of edges detected by threshold $T$ is given by

$$C(T) = \sum_{[(i, j), (k, l)] \in E(T)} \min\{|I(i, j) - T|, |I(k, l) - T|\}$$

The average contrast of all edges detected by threshold $T$: $\frac{C(T)}{\#E(T)}$

The best threshold $T_b$ is determined by the value that maximizes

$$\frac{C(T_b)}{\#E(T_b)}$$

approach for segmenting white blob against dark background

pixel with small gradient: not likely to be an edge
if not an edge, then either dark background pixel or bright blob pixel
histogram of small gradient pixels: bimodal
pixels with small gradients: valley between two modes: threshold point

FLIR (Forward Looking Infra-Red) image from NATO database

thresholded at gray level intensity 159 and 190

pixels having large gradient magnitude

2D gray level intensity—gradient space

resulting segmentation: bright object with slightly darker appendage on top

10.2.2 Multidimensional Measurement-Space Clustering
LANDSAT image: consists of seven separate images called bands
constraints of reality

1. high correlation between band-to-band pixel values

2. large amount of spatial redundancy in image data

10.3 Region Growing
10.3.1 Single-Linkage Region Growing
single-linkage region-growing schemes: regard each pixel as node in graph
neighboring pixels with similar enough properties: joined by an arc
image segments: maximal sets of pixels belonging to same connected component
simple image and the corresponding graph

two pixels connected by edge: if 4-neighbor and values differ ≤ 5

10.3.2 Hybrid-Linkage Region Growing
hybrid single-linkage techniques: more powerful than simple single-linkage
hybrid techniques: assign property vector to each pixel
property vector: depends on $K \times K$ neighborhood of the pixel
pixels similar: because neighborhoods similar in some special sense

region cannot be declared segment unless completely surrounded by edge pixels
two pixels connected by edge: if 4-neighbor and values differ ≤ 5
Pong et al. suggest an approach to segmentation based on the facet model

10.3.3 Centroid-Linkage Region Growing

In centroid-linkage region growing, the image is scanned in some predetermined manner, such as left-right, top-bottom. A pixel’s value is compared with the mean of an already existing but not necessarily completed neighboring segment. If its value and the segment’s mean value are close enough, then the pixel is added to the segment and the segment’s mean is updated. If more than one region is close enough, then it is added to the closest region. However, if the means of the two competing regions are close enough, the two regions are merged and the pixel is added to the merged region. If no neighboring region has a close-enough mean, then a new segment is established having the given pixel’s value as its first member.

caption of Fig. 10.33 explains and the figure illustrates the geometry

10.4 Hybrid-Linkage Combinations

centroid linkage, hybrid linkage: can be combined to use relative strengths

10.5 Spatial Clustering

spatial-clustering: combining clustering with spatial region growing
spatial-clustering: combine histogram-mode-seeking with region growing or
spatial-linkage technique

10.6 Split and Merge
A splitting method for segmentation begins with the entire image as the initial segment. Then the
method successively splits each of its current segments into quarters if the segment is not homogeneous
enough; that is, if the difference between the largest and smallest gray level intensities is large. A
merging method starts with an initial segmentation and successively merges regions that are similar
enough.
split-and-merge segmentation of the bulkhead image
====Fig. 10.40=====

image, segmentation, reconstruction based on least-squares-error polynomial
====V. S. Nalwa, A Guided Tour of Computer Vision, Fig. 3.23=====

10.7 Rule-Based Segmentation
rule-based seg.: easier to try different concepts without reprogramming
knowledge in the system: not application domain specific
general-purpose, scene-independent knowledge about images, grouping criteria
allowable data entry types in the Nazif and Levine rule-based segmentation
====Table 10.1=====
numerical descriptive features that can be associated with condition
====Table 10.2=====
numerical spatial features that can be associated with condition
====Table 10.3=====
logical features that can be associated with condition
====Table 10.4=====
area, region, and line analyzer actions
====Table 10.5=====
focus-of-attention and supervisor actions
====Table 10.6=====
examples of rules from the Nazif and Levine system
====Table 10.7=====

10.8 Motion-Based Segmentation
In time-varying image analysis the data are a sequence of images instead of a single image. One
paradigm under which such a sequence can arise is with a stationary camera viewing a scene containing
moving objects. In each frame of the sequence after the first frame, the moving objects appear in
different positions of the image from those in the previous frame. Thus the motion of the objects
creates a change in the images that can be used to help locate the moving objects.
(a) image $t_i$ (b) image $t_j$ (c) difference image
====Gonzalez, Digital Image Processing, Fig. 7.40=====
10.9 Summary
single-linkage region-growing schemes: simplest and most prone to errors
split-and-merge: large memory usage, excessively blocky region boundaries

Project due Jan. 11, 1994
Write a program to segment images with single-linkage region growing schemes as in Section 10.3.1 and Figure 10.25.
Try values different by less than 5, 10, 20.
Scan from left to right, top to bottom, mark each pixel with region number.
Superimpose region boundaries on the original image.