Lecture 5, Image segmentation
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GW 10 (not 10.2.3, 10.6)
Suggested Problem: 10.28

Segment the image by using the split and merge (quadtree) procedure. A region is “true” if all pixels have the same grey-level. Show the quadtree corresponding to your segmentation.

Fundamental steps in problem solving using digital image analysis

Problem
Image acquisition
Preprocessing
Segmentation
Representation and Description
Classification, recognition, interpretation
Solution

Segmentation

Divide the image contents into its constituent regions

Full segmentation: Individual objects are separated from the background and given individual ID numbers (labels).
Partial segmentation: The amount of data is reduced (usually by separating objects from background) to speed up further processing.

Segmentation is often the most difficult problem to solve in image analysis; there is no universal solution!

The problem can be made much easier if solved in cooperation with the constructor of the imaging system (choice of sensors, illumination, background etc).

Three (four) types of segmentation

Thresholding - Based on pixel intensities, often using the shape of the histogram for automation
Region-based – Group similar pixels: region growing, merge & split.
Edge-based - Search for discontinuities in the image, and try to connect objects or borders (often by a region based technique).
(Match-based- Comparison to a template (more in lecture 8 or 9 and next course))

Segmentation based on 2 basic properties of intensity values:

- Similarity: thresholding, region growing, split and merge
- Discontinuity: edges

Thresholding

A threshold \( T \) for pixel intensity classifies every pixels as belonging to objects (foreground) or background.

Fixed thresholds: the same value is used in all images
Optimal thresholding: based on the shape of the current image histogram. Search for valleys, Gaussian distributions etc.
Local (or dynamic thresholding): The image is divided into overlapping sections which are thresholded one by one.

Lighting conditions are extremely important, and it will only work under very controlled circumstances.
Threshold examples

Labeling: identifying objects

- Once the objects are separated from each other, each separate object is given an ID number.
- Use a two-pass algorithm

- How many objects are there in the image?

Edge-based Segmentation

1) Apply an edge/point detector
   - gradient operator (Sobel)
   - second derivative (Laplace)

2 a) “Threshold” edges and link and segment by:
   - local processing or
   - Hough transform

2 b) Use ex. region growing or watershed to transform the edge image into a full segmentation.
The Hough transform
Transform local information into global information in parameter space and search for common "patterns"

Represent all edge points \((x_i, y_i)\) as lines in \(a, b\) parameter space (from equation for straight line \(y = ax + b\)).

Look for points \((a', b')\) were many lines meet = edge points from a line.

Divide parameter space into accumulator cells

Hough transform
Problems with vertical lines \((a, b\) approaching infinity) are avoided by representing each point \((x, y)\) with an angle \(\theta\) and a radius \(r\).

We will then have \(x\cos \theta + y\sin \theta = r\), and each pixel will be described by a curve in the \(r-\theta\) plane, where \(\theta\) can vary in the interval +/-90 degrees.

Other parameter spaces can be used to detect e.g. the position of circles with a given radius. The Hough transform can also be applied locally to find curves that are only locally straight.

Region based segmentation
region splitting and merging, (top-down method)
1. Set up some criteria for what is a uniform area (ex mean, variance, bimodality of histogram, texture, etc)
2. Start with the full image and split it into 4 sub-images.
3. Check each sub-image. If not uniform, divide into 4 new sub-images.
4. Compare regions with neighboring regions and merge if uniform.
Repeat 2-4 until nothing more happens

The method is also called "quadtree" division.

region growing (bottom-up method)
1. Find starting points
2. Include neighboring pixels with similar features (grey-level, texture, color).
3. Continue until all pixels have been included with one of the starting points.

Problems:
Not trivial to find good starting points, difficult to automate
Need good criteria for similarity.
Ex. watershed

Watershed
(a kind of region growing)
Think of the grey-level image as a landscape. Let water rise from the bottom of each valley (the water from each valley is given its own label). As soon as the water from two valleys meet, build a dam, or watershed. These watersheds will then define the borders between different regions.

Can be used directly on the image, on an edge enhanced image or on a distance transformed image.

Example of watershed directly on a gray-level image
(AFM image of wood fibers)
Example of watershed on a binary image with “round” objects

Find individual nuclei in (2D & 3D) tissue samples

MATCH BASED SEGMENTATION

Seeded watershed

Extension to 3D

MATCH BASED SEGMENTATION

Compare a TEMPLATE to the underlying image to find objects with a certain intensity distribution or shape