Digital Image Processing

Representation
Topics

- Representation
  - Introduction
  - Chain Codes
  - Polygonal Approximations
  - Signatures
  - Boundary Segments
  - Skeletons
  - Convex Hull
  - Shape Number
  - Fourier Descriptors
Representation

• The result of segmentation should be represented and described in a form suitable for further computer processing.
  • A region can be represented in terms of its external characteristics (boundary).
  • A region can be represented in terms of its internal characteristics.
Chain Codes

- Chain codes are generated by following a boundary in a clockwise or counter-clockwise direction and assigning a direction to the segments connecting every pair of pixels.

- Disadvantage: Can be unacceptably long.
- Solution: Re-sampling (down sample) the boundary

- Disadvantage: Is starting point dependent
- Solution: Normalize the representation string to the smallest integer.
Chain Code Directions
Sample Chain Code
Down Sampling
Polygonal Approximation

- A boundary can be represented with arbitrary accuracy by a polygon.
- The approximation is exact when the number of sides is equal to the number of points in the boundary.
- Finding a polygonal representation can be very time-consuming.
Minimum Perimeter Polygons
Splitting Techniques
Signature

- A signature is a 1D representation of a boundary.
- e.g. Plotting distance to centroid as a function of angle
  - Invariant to translation

- Disadvantages:
  - Rotation and scaling dependant
  - Defined only for convex regions
Signature Example
## Boundary Segments

- Decomposing a boundary into segments simplifies representation.
- Convex Hull can be used for decomposition.
- A new segment can be started whenever a Convex Hull deficiency is entered or exited.
Boundary Segments Example
Skeleton

- The structural shape of a region can be represented by a graph.
- The structural graph is obtained by thinning the region and finding the skeleton.
The Convex Hull

- If S is the figure surface and H is the convex hull surface, H-S is called the convex deficiency. The boundary is partitioned at the points of deviation between the boundaries of S and H.

- This concept is useful to describe both an entire region and its boundary.
Boundary Descriptors

Some Simple Descriptors:

- The *length* of the boundary
- The *curvature*: the rate of change of the slope.
Shape Number

- Based on 4-directional-chain code, the shape number is the difference with the smallest magnitude. The number of digits in the shape number is called the order.
- The shape number can also be defined using 8-directional-chain code.
Fourier Descriptors

The N Cartesian coordinates \((x_i, y_i)\) of a digital boundary can be represented as:

\[ s(k) = x(k) + j.y(k) \quad \text{for } k=0 \text{ to } N-1. \]

The DFT of \(s(k)\):

\[ a(u) = \frac{1}{N} \sum_{k=0}^{N-1} s(k) e^{-2\pi j u k / N} \]

for \(u=0\) to \(N-1\).

The complex coefficients \(a(u)\) are called the *Fourier Descriptors* of the boundary. Then \(s(k)\) can be written as:

\[ s(k) = \sum_{u=0}^{N-1} a(u) e^{j2\pi u k / N} \quad \text{for } k=0 \text{ to } N-1. \]
Fourier Descriptors

- Since the high frequency DFT components of $s(k)$ only account for details, the Fourier series representation of $s(k)$ can be truncated to $M < N$ elements, resulting in the approximation $S'$

- Note that it still represents all $N$ points of the boundary, however, with less Fourier components.
Regional Descriptors

- Some Simple Descriptors
  - The Area
  - The Perimeter
  - The Compactness = $\frac{\text{perimeter}^2}{\text{Area}^2}$
Topological Descriptors

- The Number of Holes: $H$
- The number of Connected Elements: $C$
- Euler’s Number $= C - H$
Questions?