Object Description

COS791: Chapter 7

Dr. Mardé Helbig

Object Descriptions

- Need to describe properties of a group of pixels
- A set of numbers
- Called the object's descriptors
- Can compare and recognize objects by matching known object descriptors with objects in an image

Chain Codes

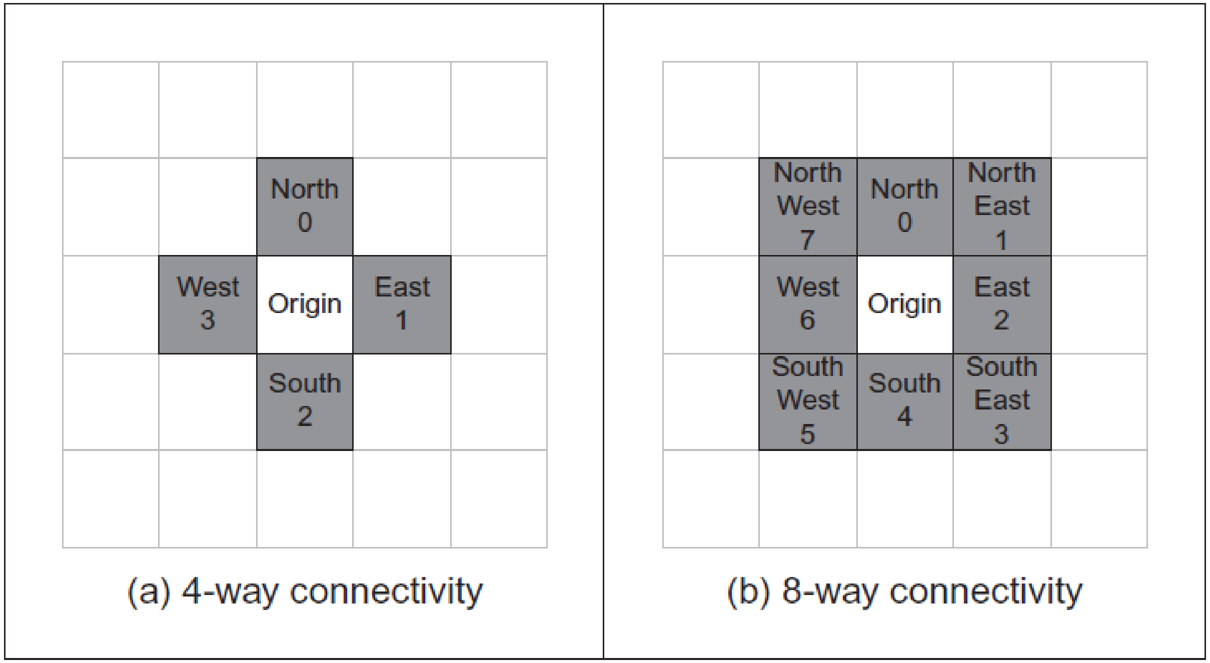
- By storing coordinates of a sequence of pixels, we can obtain a representation of a contour
- Or we can store the relative position between a sequence of pixels => basic idea behind **chain codes**
- One of the oldest techniques in computer vision – introduced in the 1960s

Chain Codes

- By storing coordinates of a sequence of pixels, we can obtain a representation of a contour
- Or we can store the relative position between a sequence of pixels => basic idea behind **chain codes**
- One of the oldest techniques in computer vision – introduced in the 1960s
- Set of pixels on the border of a shape is translated into a set of connections between them

Chain Codes

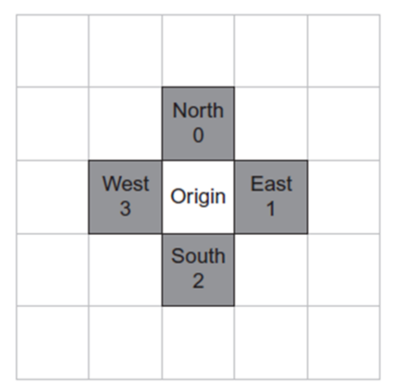
- Given a complete border, we must be able to:
  - ❖ determine the direction of the next pixel in the sequence
  - ❖ using compass directions
- Chain code is created by concatenating the number that designates the direction of the next pixel

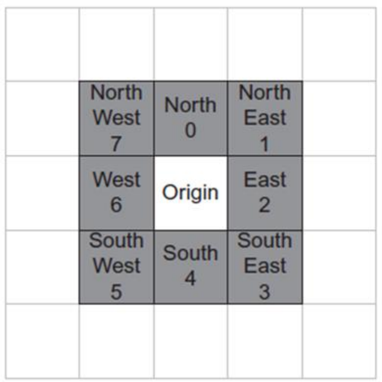


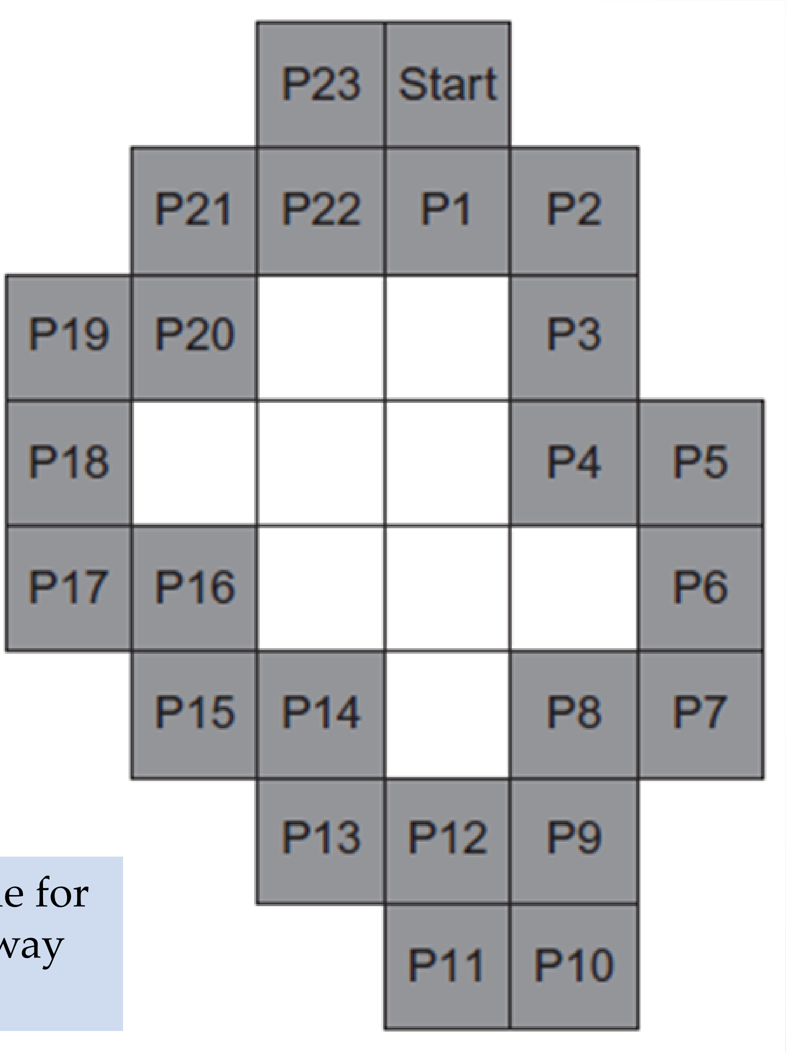
(a) 4-way connectivity

(b) 8-way connectivity

Chain Codes

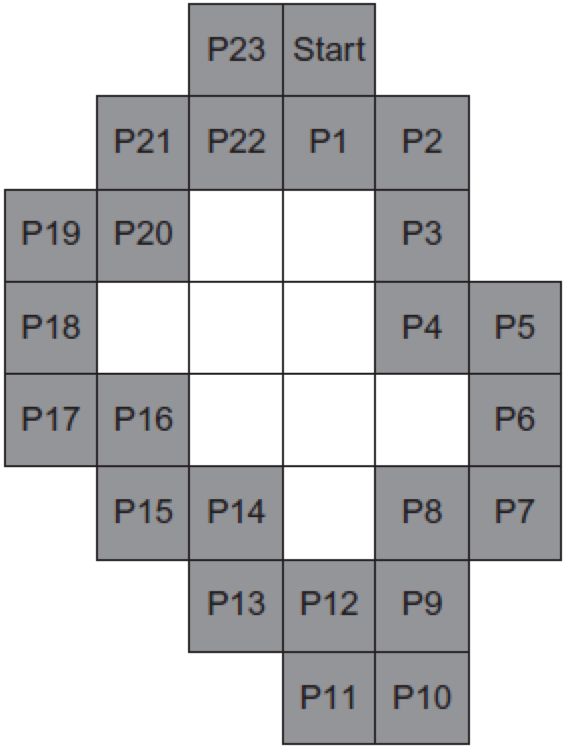






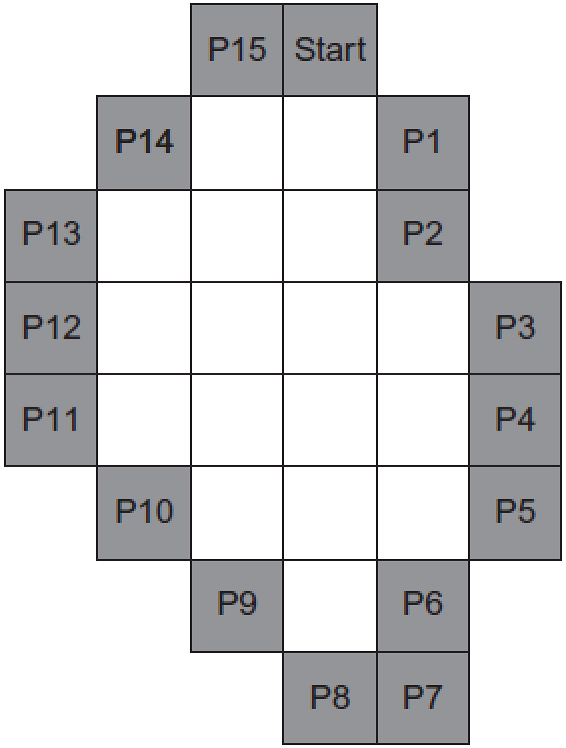
Write down the chain code for the above figure using 4-way and 8-way connectivity

Chain Codes



{2,1,2,2,1,2,2,3,2,2,3,0,3,0,3,0,3,0,0,1,0,1,0,1}

(a) Chain code given 4-way connectivity



Code = {3,4,3,4,4,5,4,6,7,7,7,0,0,1,1,2}

(b) Chain code given 8-way connectivity

Chain Codes

Shifts and Minimum integer chain code

Starting point invariance

Code = {3,4,3,4,4,5,4,6,7,7,7,0,0,1,1,2} (a) Initial chain code	Code = {4,3,4,4,5,4,6,7,7,7,0,0,1,1,2,3} (b) Result of one shift
Code = {3,4,4,5,4,6,7,7,7,0,0,1,1,2,3,4} (c) Result of two shifts	Code = {0,0,1,1,2,3,4,3,4,4,5,4,6,7,7,7} (d) Minimum integer chain code

Minimum of all possible shifts

Chain Codes

- Rotation invariance: express code as a difference of chain code – relative description removes rotation dependence
- Scale independence: re-sample boundary before coding
- Noise can have drastic effects
- BUT, chain codes are simple to use

Fourier Descriptors

- With Fourier descriptors we bring Fourier theory to shape description
- Want to characterize a shape contour by a set of numbers that represent frequency content of a whole shape
- Can select a small set of numbers (Fourier coefficients) that describes a shape

Fourier Descriptors

Two main steps to obtain a Fourier description of a curve:

1. Define a representation of a curve
2. Expand representation using Fourier theory

- Will consider Fourier descriptors of angular and complex contour representations
- The trace of a curve defines a periodic function => we will use a Fourier series expansion

Fourier Descriptors

- Although a curve in an image is composed of discrete pixels, Fourier descriptors are developed for a continuous curve
- It leads to a discrete set of Fourier descriptors
- Pixels in image are sampled points of a continuous curve in scene
- Formulations leads to the definition of the integral of a continuous curve
- In practice we have a sampled version of a continuous curve
- The expansion is approximated by means of numerical integration

Fourier Descriptors

Basis

- Coordinates of boundary pixels are x and y point coordinates
- Fourier description of these pixels gives the set of spatial frequencies that fit the boundary points
- 1st element of Fourier components (DC component) is the average value of the x and y coordinates:
  - ❖ Gives the center point of the boundary
  - ❖ Expressed in complex form
- 2nd component gives radius of circle that best fits the points

Fourier Descriptors

Basis

- A circle can be described by its zero and 1st components
- Higher order components increasingly describe detail
- How can we check whether the Fourier descriptor is correct?

Fourier Descriptors

Basis

- But what if we want descriptors that are position, scale and rotation invariant
- Need to consider more basic properties
- Need the Fourier theory for shape description

Fourier Descriptors

Fourier Expansion

- A continuous curve *c(t)* can be expressed as:

$$c(t) = \sum_{k} c_k f_k(t)$$

coefficients

basis functions

- We want to find the coefficients of the set of basis functions
- A Fourier expansion represents periodic functions by a basis defined as a set of infinite complex exponentials:

$$c(t) = \sum_{k=-\infty}^{\infty} c_k \, e^{jk\omega t}$$

fundamental frequency = $2\pi/T$, where T is period of function

Fourier Descriptors

Fourier Expansion

Main property is that it defines an orthogonal basis

$$\int_0^T f_k(t) f_j(t)\,\mathrm{d}t = 0 \qquad \text{for } k \neq j$$

This property ensures:

1. Expansion does not include redundant information
2. A simple way to compute the coefficients

Fourier Descriptors

Additional Links

- Illustrations of various shapes and number of descriptors: http://demonstrations.wolfram.com/FourierDescriptors/
- Effect of translation, rotation, scaling and position: http://fourier.eng.hmc.edu/e161/lectures/fd/node1.html

Regional Descriptors

- May want to describe the region and not the boundary
- Can use regional shape descriptors
- 2 types:
  - Basic: describes geometric properties of region
  - Moments: concentrate on density of region

Regional Descriptors

Basic: Size

- **Size or area** of region is given by:

$$A(S) = \int_x \int_y I(x, y) \mathrm{d}y \, \mathrm{d}x$$

where I=1 if pixel is within shape, 0 otherwise

- In practice, integrals are approximated by summations:

$$A(S) = \sum_x \sum_y I(x, y) \Delta A$$

ΔA is the area of 1 pixel

- ***A*** changes with scale, but is invariant to rotation

Regional Descriptors

Basic: Perimeter

- Let x(t) and y(t) denote parametric coordinates of a curve enclosing a region S.
- Then the **perimeter** of the region is given by:

$$P(S) = \int_t \sqrt{x^2(t) + y^2(t)}\mathrm{d}t$$

which is the sum of all the arcs defining the curve

- This is approximated by:

$$P(S) = \sum_i \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}$$

where x_i and y_i represent pixel i from the curve

Regional Descriptors

Basic: Compactness

- Using *A* and *P*, we can define **compactness** as follows:

$$C(S) = \frac{4\pi A(s)}{P^2(s)}$$

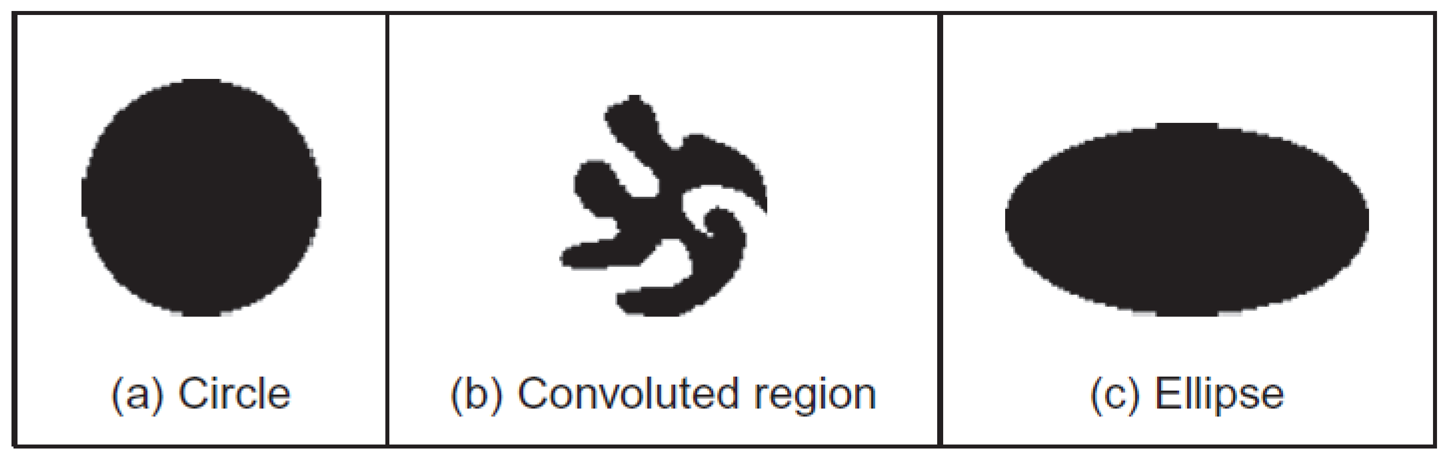
- Can re-write it as follows:

$$C(S) = \frac{A(s)}{P^2(s)/4\pi}$$

Area of circle whose perimeter is *P(S)*

Regional Descriptors

Basic: Compactness



Regional Descriptors

Basic: Dispersion and Irregularity

- Dispersion measures the ratio of major chord length to area
- Irregularity (density) is a simplified version, defined as:

$$I(S) = \frac{\pi \max((x_i - \bar{x})^2 + (y_i - \bar{y})^2)}{A(S)}$$

Area of maximum circle enclosing the region

OR

$$\mathrm{IR}(S) = \frac{\max\left(\sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}\right)}{\min\left(\sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}\right)}$$

Regional Descriptors

Basic: Issues

- Perimeter measures will vary with rotation
- Perimeter measures are more likely to be affected by noise than area measures

Regional Descriptors

Basic: Comparison of shapes

(a) Circle | (b) Convoluted region | (c) Ellipse

$A(S) = 4917$	$A(S) = 2316$	$A(S) = 6104$
$P(S) = 259.27$	$P(S) = 498.63$	$P(S) = 310.93$
$C(S) = 0.91$	$C(S) = 0.11$	$C(S) = 0.79$
$I(S) = 1.00$	$I(S) = 2.24$	$I(S) = 1.85$
$\mathrm{IR}(S) = 1.03$	$\mathrm{IR}(S) = 6.67$	$\mathrm{IR}(S) = 1.91$
(a) Descriptors for the circle	(b) Descriptors for the convoluted region	(c) Descriptors for the ellipse