6.2.4 Mark-Interior/Border-Pixel Operator

The mark-interior/border-pixel operator is nonrecursive and has a symbolic data domain. It marks all interior pixels with the label i, and all border pixels with the label b. It is based on two primitive functions. One is a two-argument primitive function h very similar to that used in the region-shrinking operator. The other one is a one-argument primitive function f. The two-argument primitive function h can recognize whether or not its arguments are identical. For identical arguments it outputs the argument. For nonidentical arguments it outputs the special symbol b, for border. The one-argument primitive function f can recognize whether or not its argument is the special symbol b. If it is, it outputs b. If not, it outputs the special symbol i, for interior. Hence

$$h(c,d) = \begin{cases} c & \text{if } c = d \\ b & \text{if } c \neq d \end{cases}$$

For nonidentical arguments → output special symbol b.

recognize argument 是否為 special symbol b.

$$f(c) = \begin{cases} b & \text{if } c = b \\ i & \text{if } c \neq b \end{cases}$$

如果 input 非 special symbol b → output special symbol i 表示 interior

The mark-interior/border-pixel operator uses the primitive function h in the following way. For the operator in the 4-connected mode, let $a_0 = x_0$. Define $a_n = h(a_{n-1}, x_n)$, $n = 1, \ldots, 4$. Then the output symbol y is defined by $y = f(a_4)$. For the operator in the 8-connected mode, let $a_0 = x_0$. Define $a_n = h(a_{n-1}, x_n)$, $n = 1, \ldots, 8$. Then the output symbol y is defined by $y = f(a_8)$.

6.2.5 Connectivity Number Operator

The connectivity number operator is nonrecursive and has a symbolic data domain. Its purpose is to classify the way a pixel is connected to its like neighbors. As shown in Fig. 6.10, there are six values of connectivity, five for border pixels and one for interior pixels. The border pixels consist of isolated pixels, edge pixels, connected pixels, branching pixels, and crossing pixels. The connectivity number operator associates with each pixel a symbol called the connectivity number of the pixel. The symbol, though a number, is really a label. It has no arithmetic number properties. The number designates which of the six kinds of connectivity a pixel has with its like neighbors.

Yokoi Connectivity Number

The definition we give here of connectivity number is based on a slight generalization of the definitions suggested by Yokoi, Toriwaki, and Fukumura (1975). The operator, as we define it, uses an 8-connected neighborhood and can be defined for either 4-connectivity or 8-connectivity.

For 4-connectivity, a pixel is an interior pixel if its value and that of each of its 4-connected neighbors are the same. In this case its 4-connectivity takes the index value 5. Otherwise the 4-connectivity of a pixel is given by the number of times a 4-connected neighbor has the same value but the corresponding three-pixel corner neighborhood does not. These corner neighbors are shown in Fig. 6.11.

```
 *****  *
  *
  *
********
  *    *
  *    *
 ****
 ****
 **** *
 ****
```

Binary Image

```
 13221  0
  2
  2
12422222
  2    2
  2    1
 1211
 1551
 1551 0
 1111
```

Labeling of the '*' Pixels

border pixels

border (5種)

interior (1種)

六種connectivity的值,

Key:

0	Isolated
1	Edge
2	Connecting
3	Branching
4	Crossing
5	Interior

interior pixels

connectivity number operator

associate 每個pixel一個symbol, 叫作這個pixel的connectivity number

這個symbol雖然是數字, 但並不是label, 沒有arithmetic number properties

Figure 6.10 Connectivity number labeling of a binary image using 8-connectivity.

的E/N/W/S neighbors

center pixel

這4個center pixel的neighbor各自的corner neighborhood

N

x_7	x_2	x_6
x_3	x_0	x_1
x_8	x_4	x_5

W E S

(a)

	x_2	x_6
		x_1

(b) x_1的corner neighborhood

x_7	x_2	
x_3		

(c) x_2的corner neighborhood

x_3		
x_8	x_4	

(d) x_3的corner neighborhood

		x_1
	x_4	x_5

(e) x_4的corner neighborhood

Figure 6.11 Corner neighborhood corresponding to each of the east, north, west, and south neighbors of the center pixel; (a) indexing pixels in a 3 × 3 neighborhood, (b) corner of x_1, (c) corner of x_2, (d) corner of x_3, and (e) corner of x_4.

For 8-connectivity, a pixel is an interior pixel if its value and that of each of its 8-connected neighbors are the same. Otherwise the 8-connectivity of a pixel is given by the number of times a 4-connected neighbor has a different value and at least one pixel in the corresponding three-pixel neighborhood corner has the same value.

The connectivity operator requires two primitive functions: a function h that can determine whether a three-pixel corner neighborhood is connected in a particular way and a function f that basically counts the number of arguments having a particular value.

For 4-connectivity, the function h of four arguments is defined by

$$h(b,c,d,e) = \begin{cases} q & \text{if } b = c \text{ and } (d \neq b \text{ or } e \neq b) \\ r & \text{if } b = c \text{ and } (d = b \text{ and } e = b) \\ s & \text{if } b \neq c \end{cases}$$

The function f of four arguments is defined by

interior

$$f(a_1,a_2,a_3,a_4) = \begin{cases} 5 & \text{if } a_1 = a_2 = a_3 = a_4 = r \\ n & \text{where } n = \#\{a_k \mid a_k = q\}, \text{ otherwise} \end{cases}$$

如果非interior pixel, f output「4-connected neighbor 有相同值, 但對應的 corner neighborhood 沒有」的個數.

connectivity number

The connectivity operator using 4-connectivity is then defined in the following way by letting

$$a_1 = h(x_0,x_1,x_6,x_2)$$

$$a_2 = h(x_0,x_2,x_7,x_3)$$

$$a_3 = h(x_0,x_3,x_8,x_4)$$

$$a_4 = h(x_0,x_4,x_5,x_1)$$

Define the connectivity number y by $y = f(a_1,a_2,a_3,a_4)$.

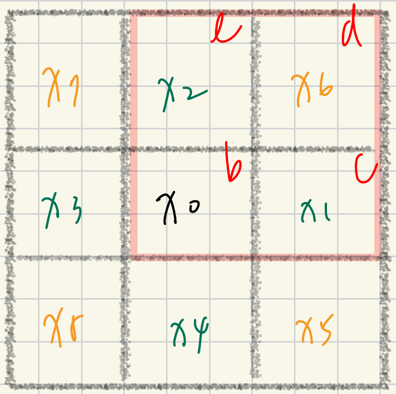
For 8-connectivity, the function h is slightly different. It is defined by

$$h(b,c,d,e) = \begin{cases} q & \text{if } b \neq c \text{ and } (d = b \text{ or } e = b) \\ r & \text{if } b = c \text{ and } (d = b \text{ and } e = b) \\ s & \text{otherwise} \end{cases}$$

Then, as before, the connectivity number y is defined by $y = f(a_1,a_2,a_3,a_4)$. Figure 6.12 illustrates the computation of the Yokoi connectivity number.

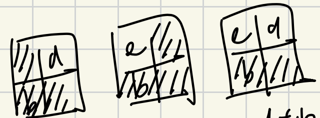
Rutovitz Connectivity Number

The Yokoi connectivity number is not the only definition of connectivity number. Another definition given by Rutovitz (1966) is based on the number of transitions from one symbol to another as one travels around the 8-neighborhood of a pixel. The definition we give here of the Rutovitz connectivity number, sometimes called a crossing number, is based on a slight generalization of the definitions suggested by Rutovitz (1966). The Rutovitz connectivity number simply counts the number of transitions from symbols that are different from that of the center pixel to symbols h(b, c, d, e)

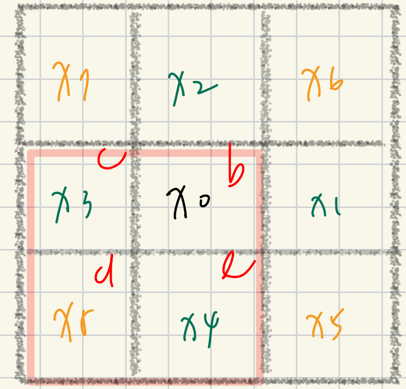


$a_1 = h(x_0, x_1, x_6, x_2)$

output g if

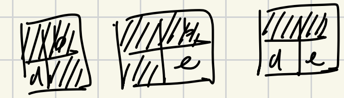


$d \neq b$ | $e \neq b$ | $d \neq b$, $e \neq b$

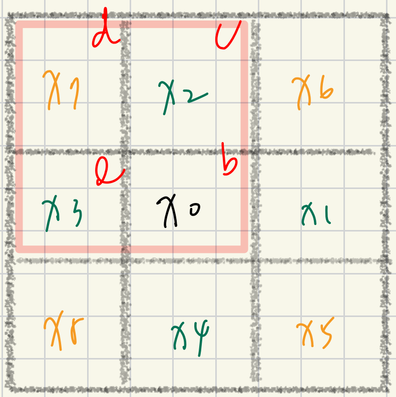


$a_3 = h(x_0, x_3, x_8, x_4)$

output g if

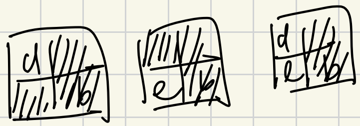


$d \neq b$ | $e \neq b$ | $d \neq b$, $e \neq b$

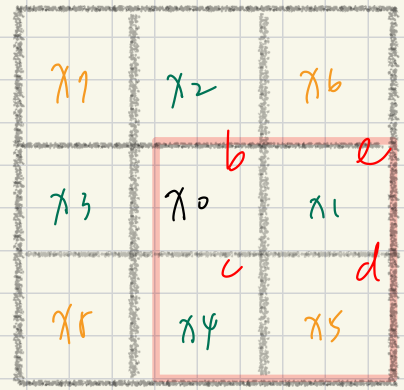


$a_2 = h(x_0, x_2, x_7, x_3)$

output g if

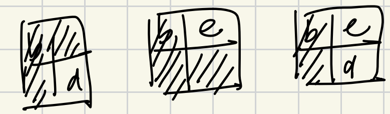


$d \neq b$ | $e \neq b$ | $d \neq b$, $e \neq b$



$a_4 = h(x_0, x_4, x_5, x_1)$

output g if



$d \neq b$ | $e \neq b$ | $d \neq b$, $e \neq b$