

TABLE 14.3-1. Shrink, Thin, and Skeletonize Conditional Mark Patterns [$M = 1$ if hit]

Table	Bond	Pattern							
S	1	0 0 1	1 0 0	0 0 0	0 0 0				
		0 1 0	0 1 0	0 1 0	0 1 0				
		0 0 0	0 0 0	1 0 0	0 0 1				
S	2	0 0 0	0 1 0	0 0 0	0 0 0				
		0 1 1	0 1 0	1 1 0	0 1 0				
		0 0 0	0 0 0	0 0 0	0 1 0				
S	3	0 0 1	0 1 1	1 1 0	1 0 0	0 0 0	0 0 0	0 0 0	0 0 0
		0 1 1	0 1 0	0 1 0	1 1 0	1 1 0	0 1 0	0 1 0	0 1 1
		0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	1 1 0	0 1 1	0 0 1
TK	4	0 1 0	0 1 0	0 0 0	0 0 0				
		0 1 1	1 1 0	1 1 0	0 1 1				
		0 0 0	0 0 0	0 1 0	0 1 0				
STK	4	0 0 1	1 1 1	1 0 0	0 0 0				
		0 1 1	0 1 0	1 1 0	0 1 0				
		0 0 1	0 0 0	1 0 0	1 1 1				
ST	5	1 1 0	0 1 0	0 1 1	0 0 1				
		0 1 1	0 1 1	1 1 0	0 1 1				
		0 0 0	0 0 1	0 0 0	0 1 0				
ST	5	0 1 1	1 1 0	0 0 0	0 0 0				
		0 1 1	1 1 0	1 1 0	0 1 1				
		0 0 0	0 0 0	1 1 0	0 1 1				
ST	6	1 1 0	0 1 1						
		0 1 1	1 1 0						
		0 0 1	1 0 0						
STK	6	1 1 1	0 1 1	1 1 1	1 1 0	1 0 0	0 0 0	0 0 0	0 0 1
		0 1 1	0 1 1	1 1 0	1 1 0	1 1 0	1 1 0	0 1 1	0 1 1
		0 0 0	0 0 1	0 0 0	1 0 0	1 1 0	1 1 1	1 1 1	0 1 1

(Continued)

TABLE 14.3-1 (Continued)

Table	Bond	Pattern							
STK	7	1 1 1	1 1 1	1 0 0	0 0 1				
		0 1 1	1 1 0	1 1 0	0 1 1				
		0 0 1	1 0 0	1 1 1	1 1 1				
STK	8	0 1 1	1 1 1	1 1 0	0 0 0				
		0 1 1	1 1 1	1 1 0	1 1 1				
		0 1 1	0 0 0	1 1 0	1 1 1				
STK	9	1 1 1	0 1 1	1 1 1	1 1 1	1 1 1	1 1 0	1 0 0	0 0 1
		0 1 1	0 1 1	1 1 1	1 1 1	1 1 0	1 1 0	1 1 1	1 1 1
		0 1 1	1 1 1	1 0 0	0 0 1	1 1 0	1 1 1	1 1 1	1 1 1
STK	10	1 1 1	1 1 1	1 1 1	1 0 1				
		0 1 1	1 1 1	1 1 0	1 1 1				
		1 1 1	1 0 1	1 1 1	1 1 1				
K	11	1 1 1	1 1 1	1 1 0	0 1 1				
		1 1 1	1 1 1	1 1 1	1 1 1				
		0 1 1	1 1 0	1 1 1	1 1 1				

Figure 14.3-2 shows an example of the shrinking of a binary image for four and 13 iterations of the algorithm. No further shrinking occurs for more than 13 iterations. At this point, the shrinking operation has become *idempotent* (i. e., reapplication evokes no further change. This shrinking algorithm does not shrink the symmetric original ring object to a ring that is also symmetric because of some of the conditional mark patterns of Table 14.3-2, which are necessary to ensure that objects of even dimension shrink to a single pixel. For the same reason, the shrink ring is not minimally connected.

14.3.2. Binary Image Thinning

The following is a definition of *thinning*:

Thin. Erase black pixels such that an object without holes erodes to a minimally connected stroke located equidistant from its nearest outer boundaries, and an object with holes erodes to a minimally connected ring midway between each hole and its nearest outer boundary.

TABLE 14.3-2. Shrink and Thin Unconditional Mark Patterns $[P(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7) = 1 \text{ if hit}]^a$

Pattern							
Spur				Single 4-connection			
0 0 <i>M</i>	<i>M</i> 0 0	0 0 0	0 0 0				
0 <i>M</i> 0	0 <i>M</i> 0	0 <i>M</i> 0	0 <i>MM</i>				
0 0 0	0 0 0	0 <i>M</i> 0	0 0 0				
L Cluster (thin only)							
0 0 <i>M</i>	0 <i>MM</i>	<i>MM</i> 0	<i>M</i> 0 0	0 0 0	0 0 0	0 0 0	0 0 0
0 <i>MM</i>	0 <i>M</i> 0	0 <i>M</i> 0	<i>MM</i> 0	<i>MM</i> 0	0 <i>M</i> 0	0 <i>M</i> 0	0 <i>MM</i>
0 0 0	0 0 0	0 0 0	0 0 0	<i>M</i> 0 0	<i>MM</i> 0	0 <i>MM</i>	0 0 <i>M</i>
4-Connected offset							
0 <i>MM</i>	<i>MM</i> 0	0 <i>M</i> 0	0 0 <i>M</i>				
<i>MM</i> 0	0 <i>MM</i>	0 <i>MM</i>	0 <i>MM</i>				
0 0 0	0 0 0	0 0 <i>M</i>	0 <i>M</i> 0				
Spur corner cluster							
0 <i>A M</i>	<i>M B</i> 0	0 0 <i>M</i>	<i>M</i> 0 0				
0 <i>M B</i>	<i>A M</i> 0	<i>A M</i> 0	0 <i>M B</i>				
<i>M</i> 0 0	0 0 <i>M</i>	<i>M B</i> 0	0 <i>A M</i>				
Corner cluster							
<i>MMD</i>							
<i>MMD</i>							
<i>DD D</i>							
Tee branch							
<i>D M</i> 0	0 <i>M D</i>	0 0 <i>D</i>	<i>D</i> 0 0	<i>D M D</i>	0 <i>M</i> 0	0 <i>M</i> 0	<i>D M D</i>
<i>MMM</i>	<i>MMM</i>	<i>MMM</i>	<i>MMM</i>	<i>MM</i> 0	<i>MM</i> 0	0 <i>MM</i>	0 <i>MM</i>
<i>D</i> 0 0	0 0 <i>D</i>	0 <i>M D</i>	<i>D M</i> 0	0 <i>M</i> 0	<i>D M D</i>	<i>D M D</i>	0 <i>M</i> 0
Vee branch							
<i>M D M</i>	<i>M D C</i>	<i>C B A</i>	<i>A D M</i>				
<i>D M D</i>	<i>D M B</i>	<i>D M D</i>	<i>B M D</i>				
<i>A B C</i>	<i>M D A</i>	<i>M D M</i>	<i>C D M</i>				
Diagonal branch							
<i>D M</i> 0	0 <i>M D</i>	<i>D</i> 0 <i>M</i>	<i>M</i> 0 <i>D</i>				
0 <i>MM</i>	<i>MM</i> 0	<i>MM</i> 0	0 <i>MM</i>				
<i>M</i> 0 <i>D</i>	<i>D</i> 0 <i>M</i>	0 <i>M D</i>	<i>D M</i> 0				

^a $A \cup B \cup C = 1 \quad D = 0 \cup 1 \quad A \cup B = 1.$

TABLE 14.3-3. Skeletonize Unconditional Mark Patterns
 $[P(M, M_0, M_1, M_2, M_3, M_4, M_5, M_6, M_7) = 1 \text{ if hit}]^a$

Pattern											
Spur											
0	0	0	0	0	0	0	0	M	M	0	0
0	M	0	0	M	0	0	M	0	0	M	0
0	0	M	M	0	0	0	0	0	0	0	0
Single 4-connection											
0	0	0	0	0	0	0	0	0	0	M	0
0	M	0	0	M	M	M	M	0	0	M	0
0	M	0	0	0	0	0	0	0	0	0	0
L corner											
0	M	0	0	M	0	0	0	0	0	0	0
0	M	M	M	M	0	0	M	M	M	M	0
0	0	0	0	0	0	0	M	0	0	M	0
Corner cluster											
D	M	M	D	D	D	M	M	D	D	D	D
D	M	M	M	M	D	M	M	D	D	M	M
D	D	D	M	M	D	D	D	D	D	M	M
Tee branch											
D	M	D	D	M	D	D	D	D	D	M	D
M	M	M	M	M	D	M	M	M	D	M	M
D	0	0	D	M	D	D	M	D	D	M	D
Vee branch											
M	D	M	M	D	C	C	B	A	A	D	M
D	M	D	D	M	B	D	M	D	B	M	D
A	B	C	M	D	A	M	D	M	C	D	M
Digonal branch											
D	M	0	0	M	D	D	0	M	M	0	D
0	M	M	M	M	0	M	M	0	0	M	M
M	0	D	D	0	M	0	M	D	D	M	0

^a $A \cup B \cup C = 1 \quad D = 0 \cup 1.$