Morfoloji

İçindekiler

Ön Bilgi

Morphology kelimesi, biyolojide hayvan ve bitkilerin şekil ve yapılarını inceleyen bir dalı işaret eder. Benzer manada görüntüdeki bileşenlerin şekil ve yapılarını inceleyeceğiz.

Giriş İmgesi ➔ Morfolojik İşleme ➔ Nesnelerin Özellikleri

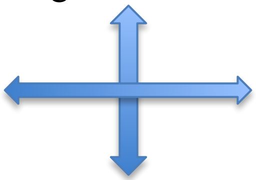
Giriş imgesi genellikle iki seviyeli görüntülerdir.

Morfolojik işlemler küme teorisine dayanmaktadır. Örneğin aşağıdaki şekilde bir kümenin yansıması ve ötelenmesi gösterilmektedir.

Ön Bilgi-Bağlılık

0	0	0	0	0	0	0	0
0	1	1	0	0	1	1	1
0	1	1	0	0	0	1	1
0	1	1	0	0	0	0	0
0	0	0	1	1	0	0	0
0	0	0	1	1	0	0	0
0	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0

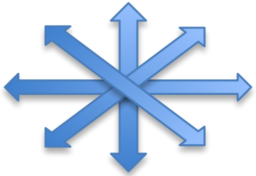
4-bağlılık ile incelenirse



3 bağımsız nesne bulunur

0	0	0	0	0	0	0	0
0	1	1	0	0	1	1	1
0	1	1	0	0	0	1	1
0	1	1	0	0	0	0	0
0	0	0	1	1	0	0	0
0	0	0	1	1	0	0	0
0	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0

8-bağlılık ile incelenirse



2 bağımsız nesne bulunur

0	0	0	0	0	0	0	0
0	1	1	0	0	1	1	1
0	1	1	0	0	0	1	1
0	1	1	0	0	0	0	0
0	0	0	1	1	0	0	0
0	0	0	1	1	0	0	0
0	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0

Ön Bilgi-Yapısal Element (Maske)

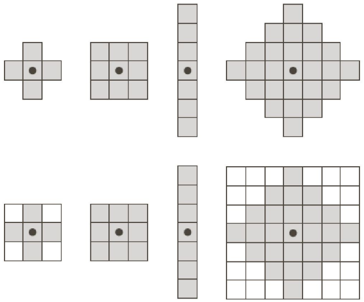


FIGURE 9.2 First row: Examples of structuring elements. Second row: Structuring elements converted to rectangular arrays. The dots denote the centers of the SEs.

Yapısal element (structuring element - SE), görüntü üzerinde gezdirilen maskedir.

Ön Bilgi

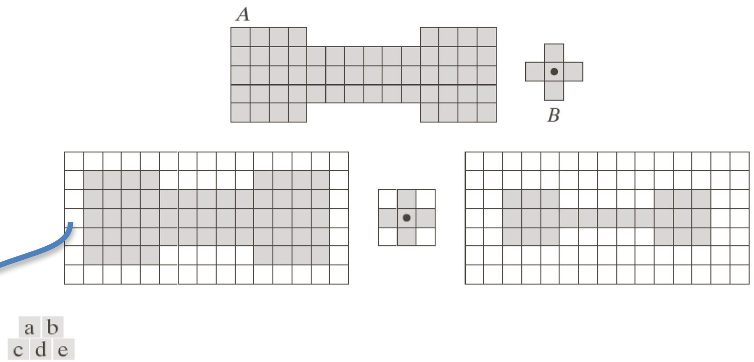


FIGURE 9.3 (a) A set (each shaded square is a member of the set). (b) A structuring element. (c) The set padded with background elements to form a rectangular array and provide a background border. (d) Structuring element as a rectangular array. (e) Set processed by the structuring element.

İnceltme işlemi yapıldı

Padding işlemi görüntünün genişletilmesidir. Bu işlem yapısal elementin görüntü sınırlarında çalışabilmesi için yapılır.

Aşınma (Erosion) – ($A \ominus B$)

İmge çerçevesi ile yapısal elementin tüm piksellerin **AND** işlemine tabi tutulmasıdır. Yapısal elementle tam örtüşme varsa 1, diğer durumlarda 0 sonucunu üretir.

Örnek)

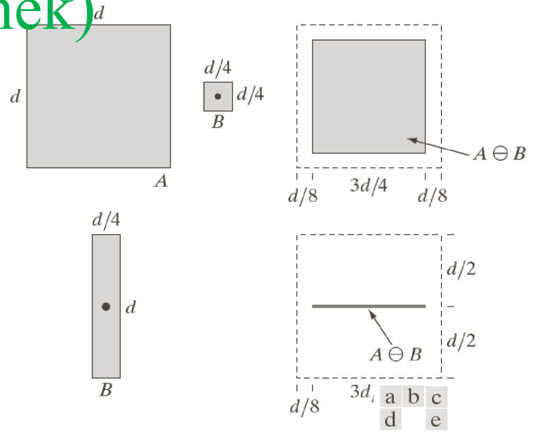


FIGURE 9.4 (a) Set A. (b) Square structuring element, B. (c) Erosion of A by B, shown shaded. (d) Elongated structuring element. (e) Erosion of A by B using this element. The dotted border in (c) and (e) is the boundary of set A, shown only for reference.

Bu örneğin açık hali

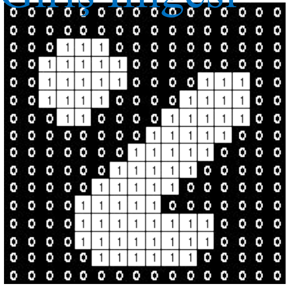
İki Seviyeli Görüntü	**Yapısal Element**
0 0 0 0 0 0 0 0 0 0 0 0 0	1
0 0 0 0 0 0 0 0 0 0 0 0 0	1
0 0 0 1 1 1 1 1 1 1 0 0 0	1
0 0 0 1 1 1 1 1 1 1 0 0 0	1
0 0 0 1 1 1 1 1 1 1 0 0 0	1
0 0 0 1 1 1 1 1 1 1 0 0 0	
0 0 0 1 1 1 1 1 1 1 0 0 0	
0 0 0 0 0 0 0 0 0 0 0 0 0	
0 0 0 0 0 0 0 0 0 0 0 0 0	

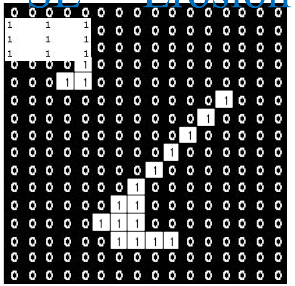
Erosion İşlemi Sonucu

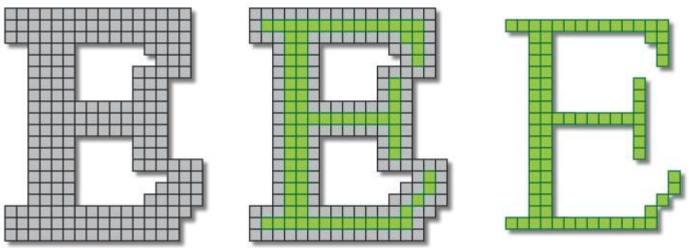
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0

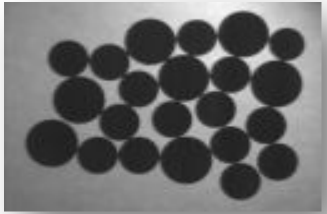
Aşınma (Erosion) - Örnekler

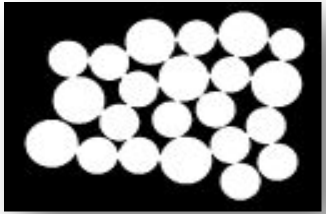
Giriş İmgesi SE Erosion Sonucu

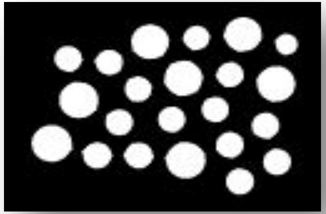






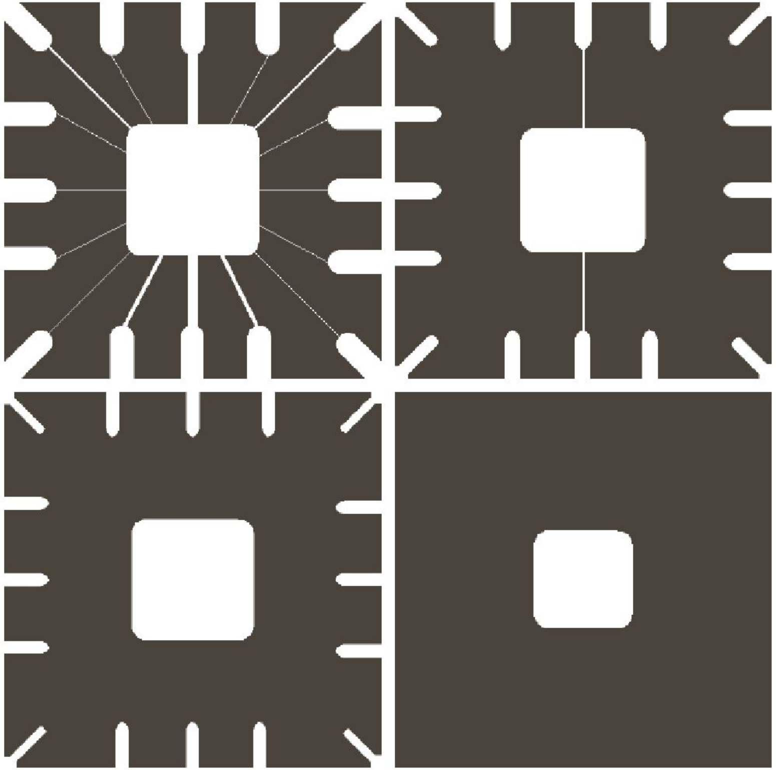






Aşınma (Erosion) - Örnek

Bağlantılı nesneleri ayırmada kullanılır.

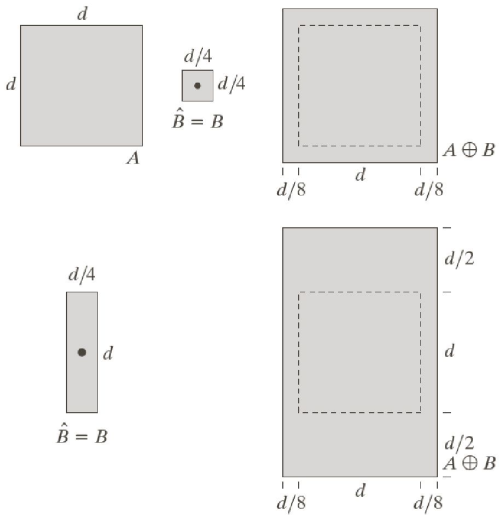


a b
c d

FIGURE 9.5 Using erosion to remove image components. (a) A 486×486 binary image of a wire-bond mask. (b)–(d) Image eroded using square structuring elements of sizes 11×11, 15×15, and 45×45, respectively. The elements of the SEs were all 1s.

Genişleme (Dilation) – ($A \oplus B$)

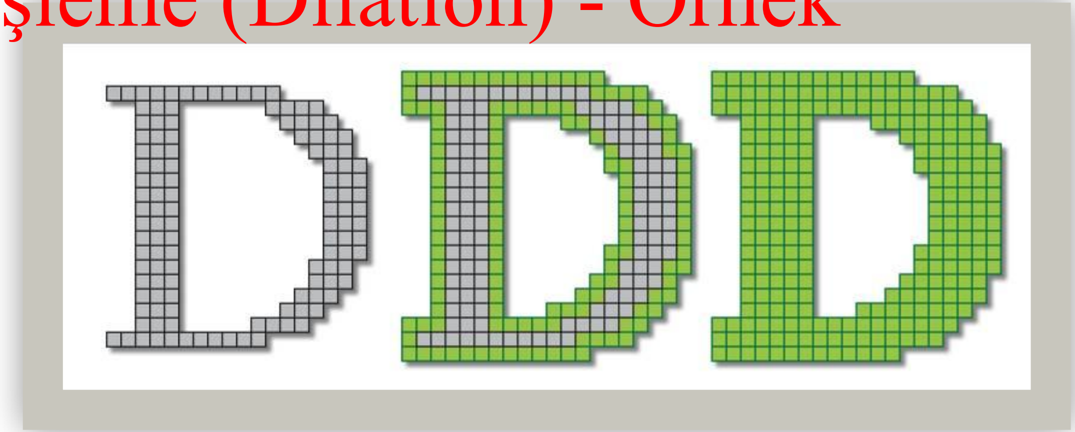
İmge çerçevesindeki her bir nesne pikselinin yapısal element yardımıyla genişletilmesi işlemidir. Nesne pikseli üzerinde yapısal element koyulup **OR** işlemi sonucu çıkış imgesine yazılır. Kopuk nesneleri bağlamada kullanılır.

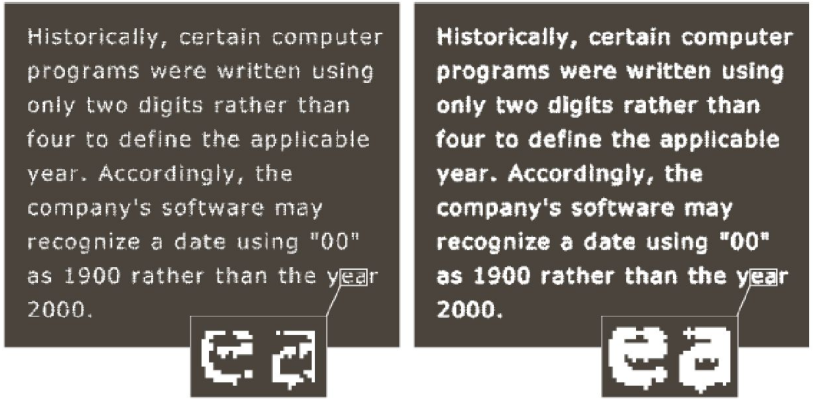


a b c
d e

FIGURE 9.6
(a) Set A.
(b) Square structuring element (the dot denotes the origin).
(c) Dilation of A by B, shown shaded.
(d) Elongated structuring element. (e) Dilation of A using this element. The dotted border in (c) and (e) is the boundary of set A, shown only for reference

Genişleme (Dilation) - Örnek





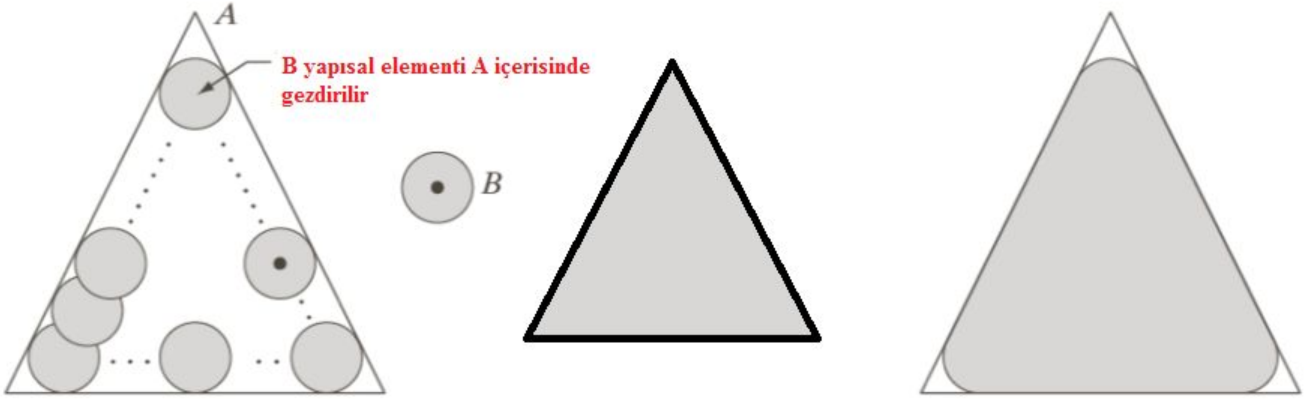
0	1	0
1	1	1
0	1	0

a c
b

FIGURE 9.7 (a) Sample text of poor resolution with broken characters (see magnified view). (b) Structuring element. (c) Dilation of (a) by (b). Broken segments were joined.

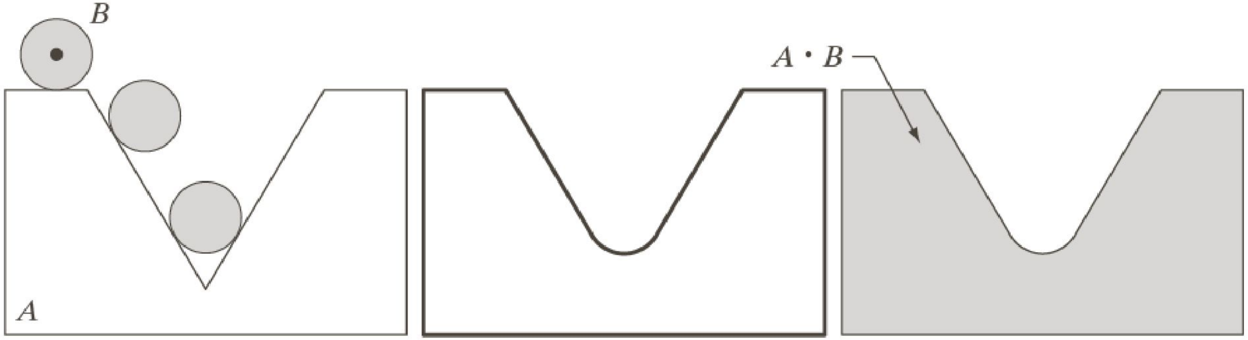
Açma (Opening) – $(A \circ B)$

Yapısal elementin nesne içerisinde gezdirilmesi sonucu temas ettiği piksellerin tutulup diğerlerinin elenmesi işlemidir. Bunu yapabilmek için A imgesi B yapısal elementiyle ilk önce **aşınma**, daha sonra **genişleme** işlemine tabi tutulur. Aşağıdaki örneğe dikkatli bakarsak, aşınma sonucunda keskin bir üçgen elde edilirken, bu sonuç genişleme işlemiyle yumuşatılır.



Kapama (Closing) – (A ¥ B)

Yapısal elementin nesne dışında gezdirilmesi sonucu dışarıda nesneye ait olmayan ve elementin temas ettiği tüm piksellerin nesneye eklenmesi işlemidir. Bunu yapabilmek için A imgesi B yapısal elementiyle ilk önce **genişleme**, daha sonra **aşınma** işlemine tabi tutulur.



Örnek – (Aşınma, Genişleme, Açma, Kapama)

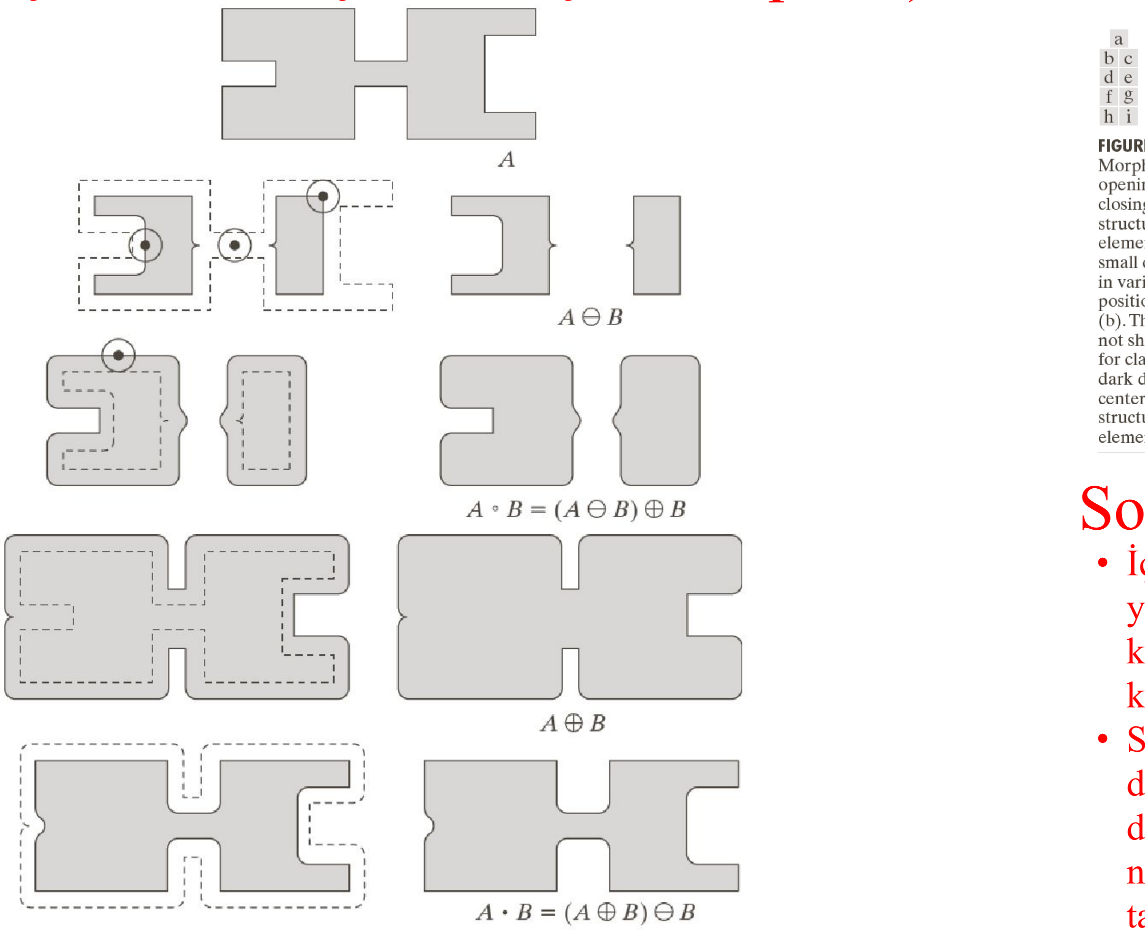
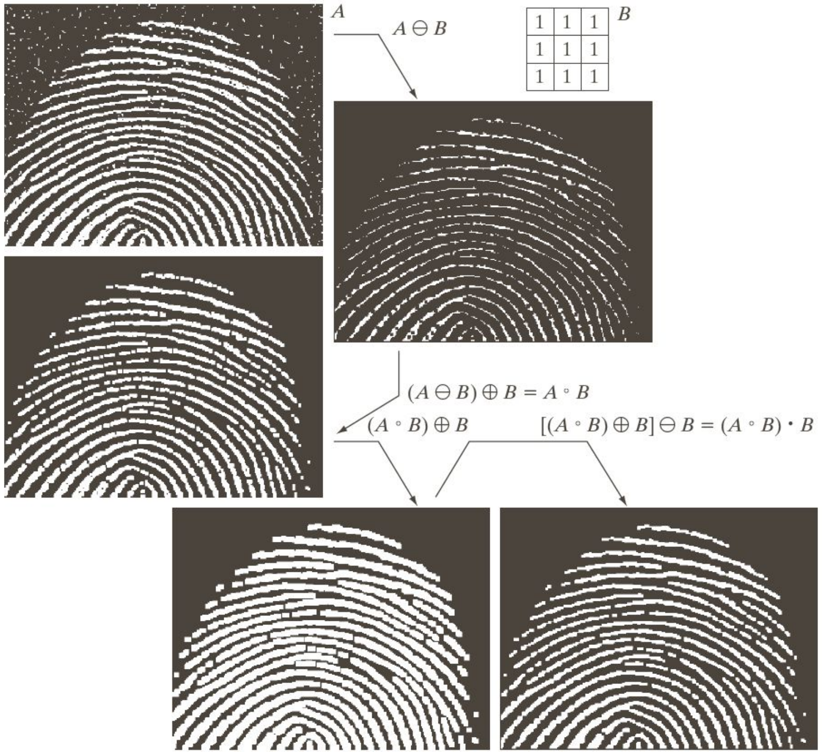


FIGURE 9.10 Morphological opening and closing. The structuring element is the small circle shown in various positions in (b). The SE was not shaded here for clarity. The dark dot is the center of the structuring element.

Sonuç olarak

- İç kenarların yumuşadığı, dış kenarların değişmeden kaldığı görülmektedir.
- Sol iç taraftaki beyaz dikdörtgenin çok değişime uğramasının nedeni yapısal elementle tam uyuşmamasıdır.

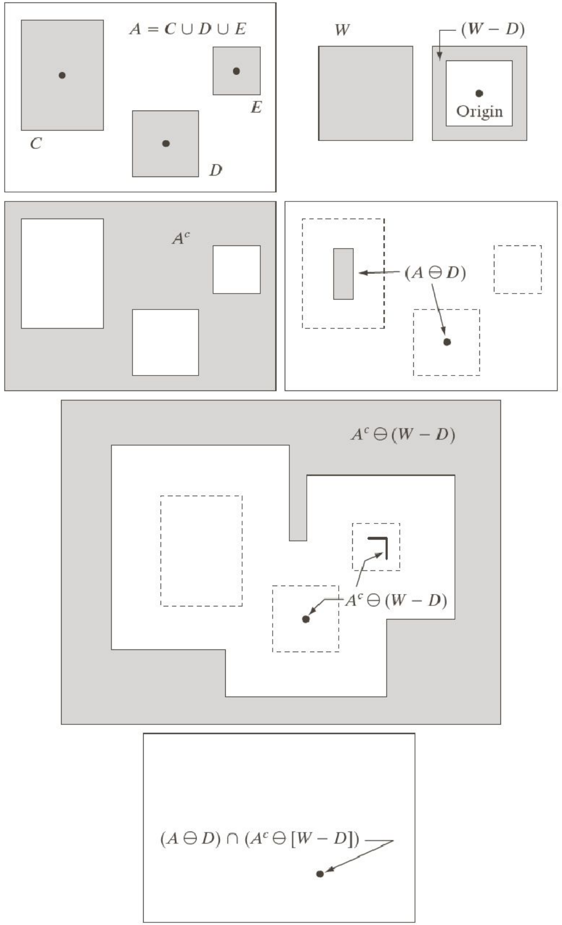
Örnek – (Aşınma, Genişleme, Açma, Kapama)



a b c d e f

FIGURE 9.11
(a) Noisy image.
(b) Structuring element.
(c) Eroded image.
(d) Opening of A.
(e) Dilation of the opening.
(f) Closing of the opening.
(Original image courtesy of the National Institute of Standards and Technology.)

Şekil yakalama için Hit-or-Miss Dönüşümü



a b
c d
e
f

FIGURE 9.12 (a) Set A. (b) A window, W, and the local background of D with respect to W, $(W - D)$. (c) Complement of A. (d) Erosion of A by D. (e) Erosion of A^c by $(W - D)$. (f) Intersection of (d) and (e), showing the location of the origin of D, as desired. The dots indicate the origins of C, D, and E.

Sınır Çıkarımı

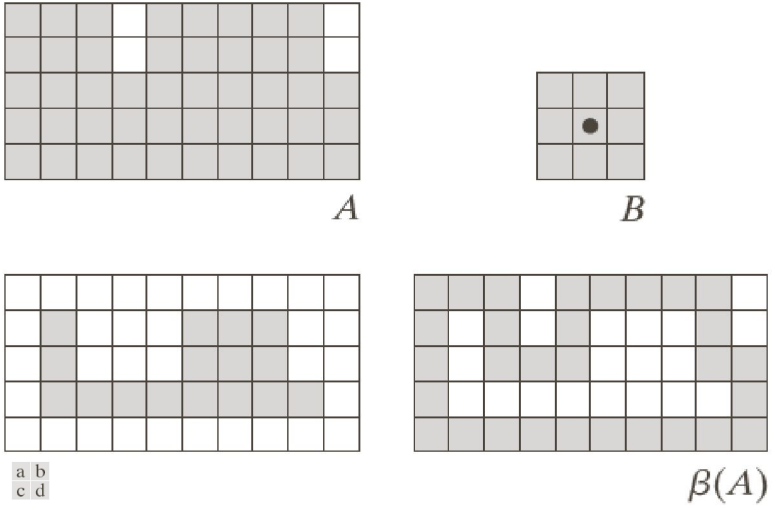


FIGURE 9.13 (a) Set A. (b) Structuring element B. (c) A eroded by B. (d) Boundary, given by the set difference between A and its erosion.

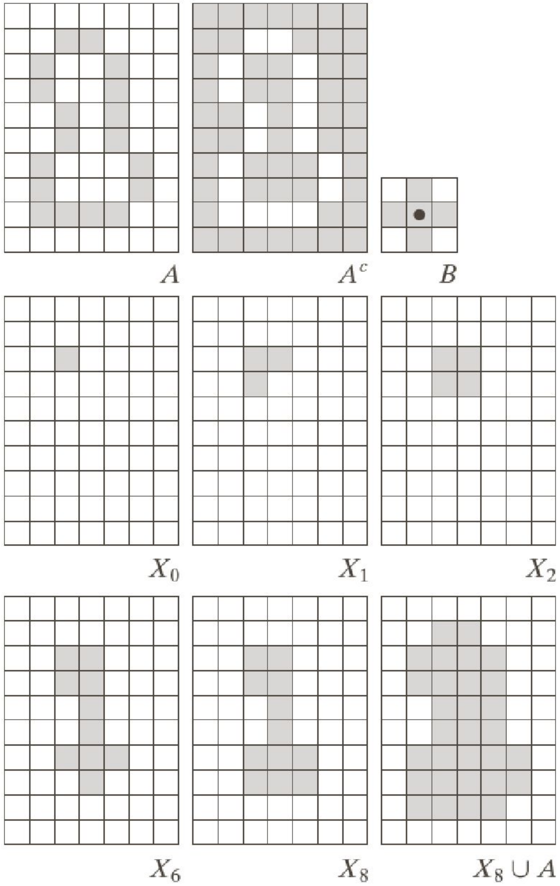
Sınır Çıkarımı

a b

FIGURE 9.14 (a) A simple binary image, with 1s represented in white. (b) Result of using Eq. (9.5-1) with the structuring element in Fig. 9.13(b).

$$\beta(A) = A - (A \ominus B) \qquad (9.5\text{-}1)$$

Delik doldurma (Yöntem-1)



a b c
d e f
g h i

FIGURE 9.15 Hole filling. (a) Set *A* (shown shaded). (b) Complement of *A*. (c) Structuring element *B*. (d) Initial point inside the boundary. (e)–(h) Various steps of Eq. (9.5-2). (i) Final result [union of (a) and (h)].

ADIMLAR

1. İç bölgedeki piksele konumlan.
2. Yapısal elementi kullanarak tüm bağlı bileşenleri bul.
3. Sonucu orijinal imgeyle birleştir.

Örnek - Delik doldurma (Yöntem-1)

a b c

FIGURE 9.16 (a) Binary image (the white dot inside one of the regions is the starting point for the hole-filling algorithm). (b) Result of filling that region. (c) Result of filling all holes.

Bağlı Bileşenlerin Çıkarımı

Nesneye ait herhangi bir pikselden başla ve genişleyerek nesneye ait diğer piksellere ulaş.

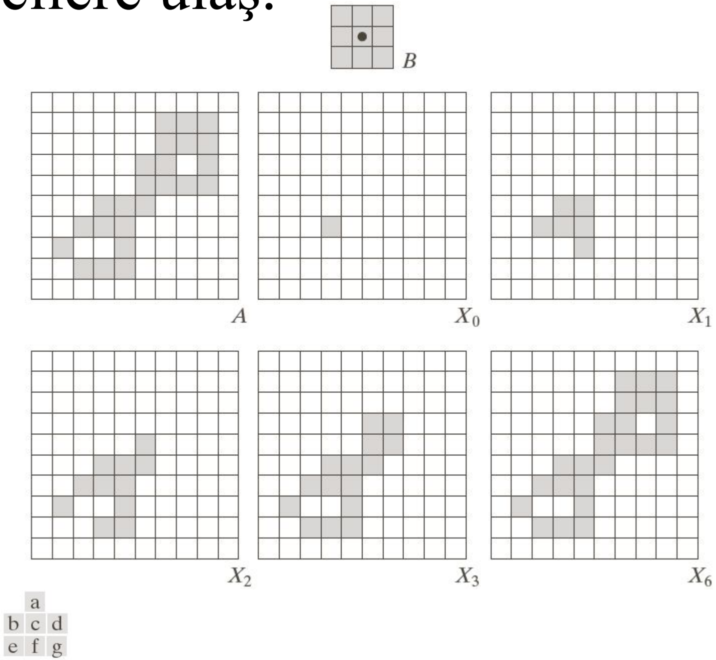
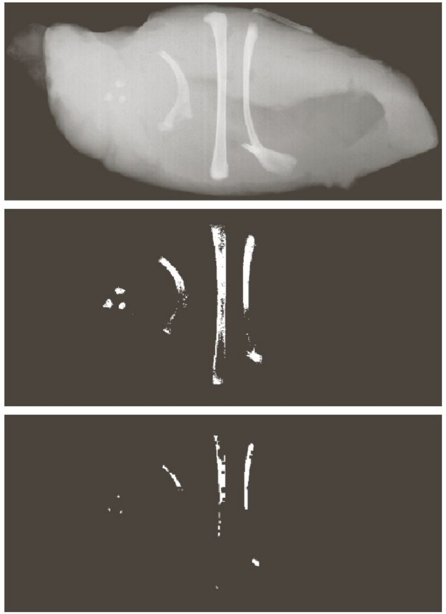


FIGURE 9.17 Extracting connected components. (a) Structuring element. (b) Array containing a set with one connected component. (c) Initial array containing a 1 in the region of the connected component. (d)–(g) Various steps in the iteration of Eq. (9.5-3).

Bağlı Bileşen Uygulaması



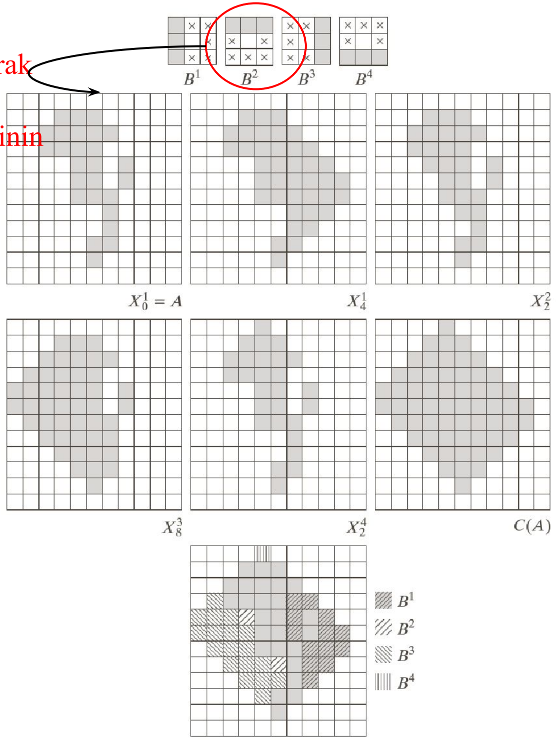
Connected component	No. of pixels in connected comp
01	11
02	9
03	9
04	39
05	133
06	1
07	1
08	743
09	7
10	11
11	11
12	9
13	9
14	674
15	85

a
b
c d

FIGURE 9.18 (a) X-ray image of chicken filet with bone fragments. (b) Thresholded image. (c) Image eroded with a 5×5 structuring element of 1s. (d) Number of pixels in the connected components of (c). (Image courtesy of NTB Elektronische Geraete GmbH, Diepholz, Germany, www.ntbxray.com.)

Dış Bükey Gövde (Convex Hull)

Bu yapısal elementi gördüğün yeri doldurarak ilerle. **x** sembolü, o noktadaki piksel değerinin önemli olmadığını göstermektedir.

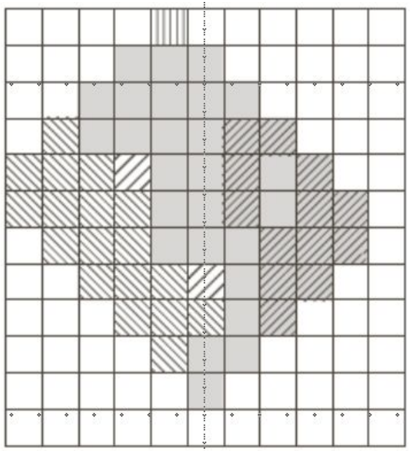


a
b c d
e f g
h

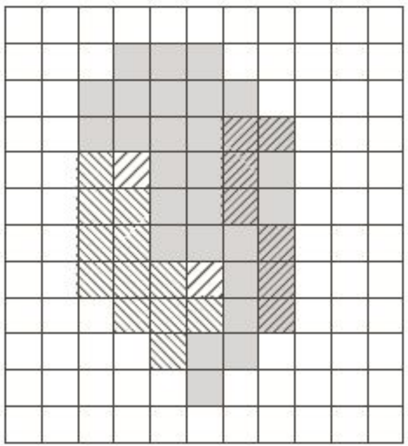
FIGURE 9.19 (a) Structuring elements. (b) Set A. (c)–(f) Results of convergence with the structuring elements shown in (a). (g) Convex hull. (h) Convex hull showing the contribution of each structuring element.

Sınırlı Dış Bükey Gövde

Sınırlı olmayan



Sınırlı



İnceltme

Bu yapısal elementlere uyan pikseller kalır, uymayanlar silinir

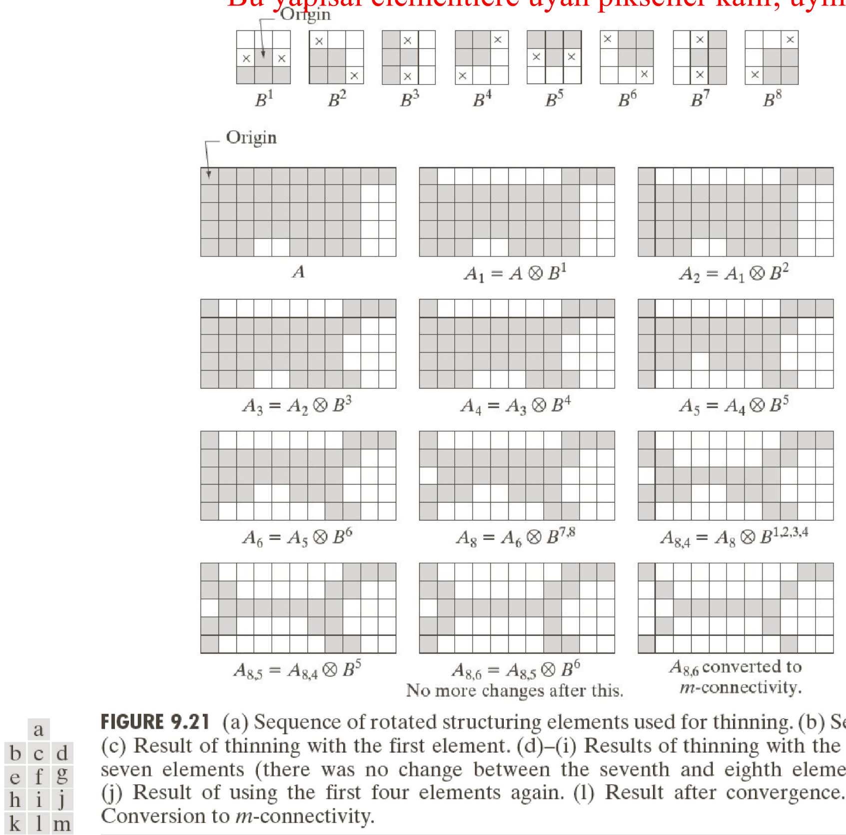
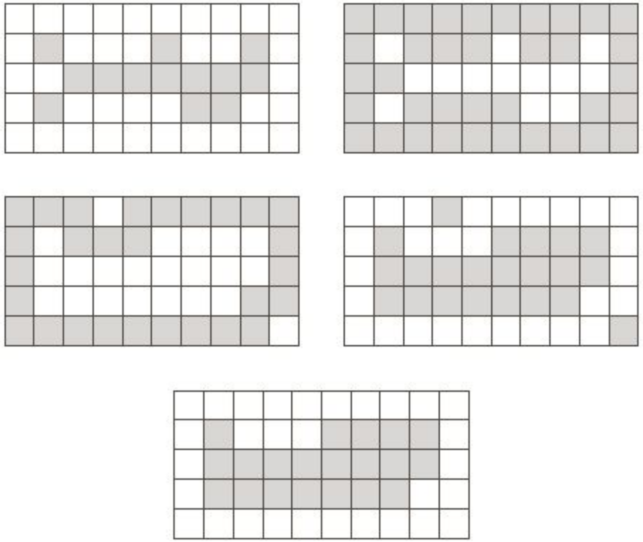


FIGURE 9.21 (a) Sequence of rotated structuring elements used for thinning. (b) Set A. (c) Result of thinning with the first element. (d)–(i) Results of thinning with the next seven elements (there was no change between the seventh and eighth elements). (j) Result of using the first four elements again. (l) Result after convergence. (m) Conversion to m-connectivity.

Bir piksel hem 4 hem de 8 komşuluğa sahipse o piksel silinir (m-connectivity).

Kalınlaştırma

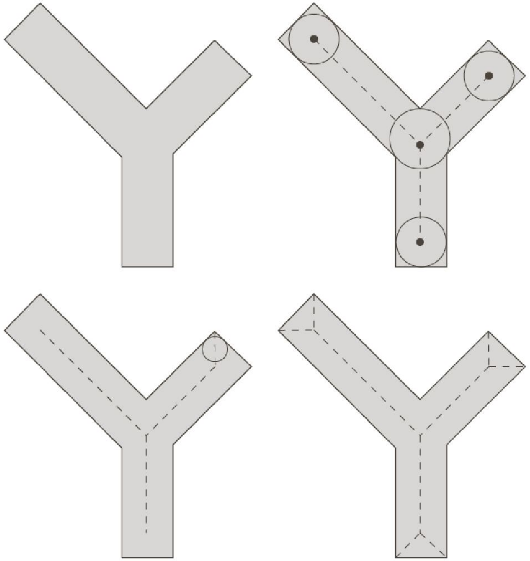
Orijinal imge ➔ Komplement al ➔ İncelt ➔ Komplement al ➔ Bağlı olmayan bileşenleri ele



a b
c d
e

FIGURE 9.22 (a) Set A. (b) Complement of A. (c) Result of thinning the complement of A. (d) Thickened set obtained by complementing (c). (e) Final result, with no disconnected points.

İskelet Bulma



a b
c d

FIGURE 9.23
(a) Set A.
(b) Various positions of maximum disks with centers on the skeleton of A.
(c) Another maximum disk on a different segment of the skeleton of A.
(d) Complete skeleton.

İskelet Bulma Formülasyonu

İskelet bulma işlemi aşınma ve açma kullanılarak elde edilebilir:

$$S(A) = \bigcup_{k=0}^{K} S_k(A) \qquad (9.5-11)$$

$$S_k(A) = (A \ominus kB) - (A \ominus kB) \circ B \qquad (9.5-12)$$

$$(A \ominus kB) = ((\ldots((A \ominus B) \ominus B) \ominus \ldots) \ominus B) \qquad (9.5-13)$$

$$K = \max\{ k \mid (A \ominus kB) \neq \emptyset\}$$

K+1 adımda A’nın B ile aşınma sonucu boş küme olmalı.

İskelet kullanılarak orijinal imge tekrar elde edilebilir:

$$A = \bigcup_{k=0}^{K} (S_k(A) \oplus kB) \qquad (9.5-15)$$

Örnek - İskelet Bulma ve Tekrar insa etme

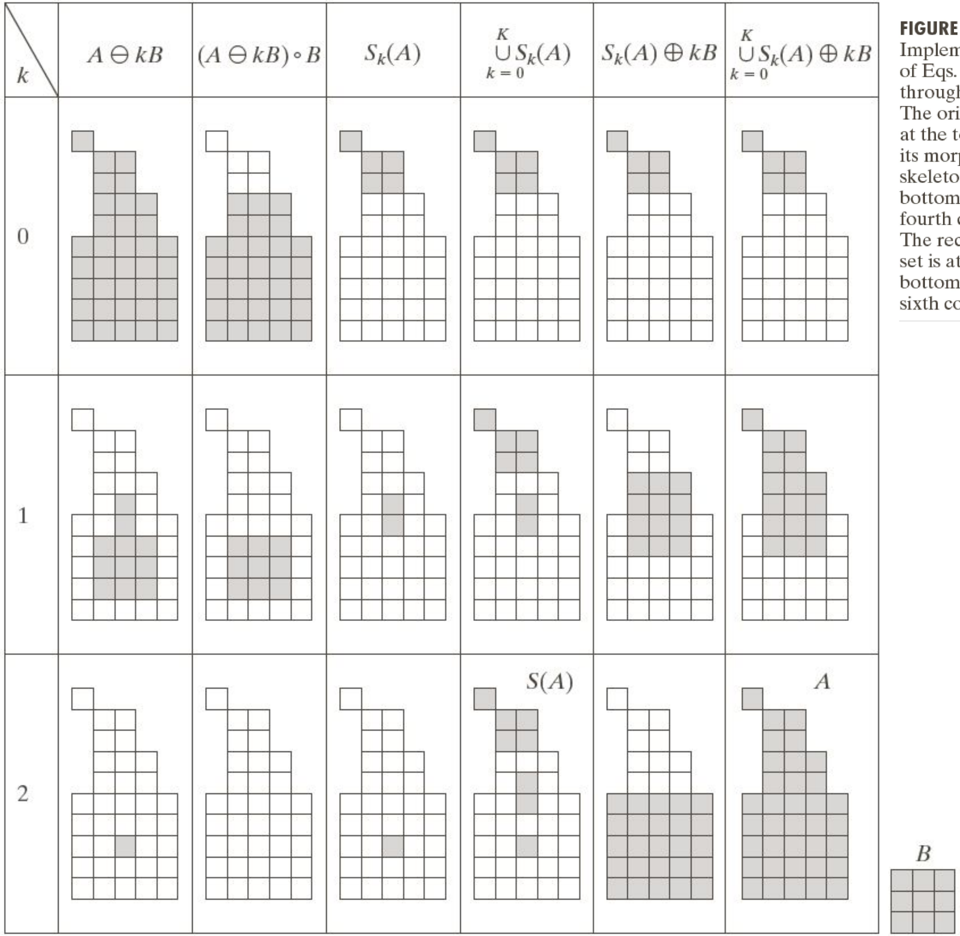
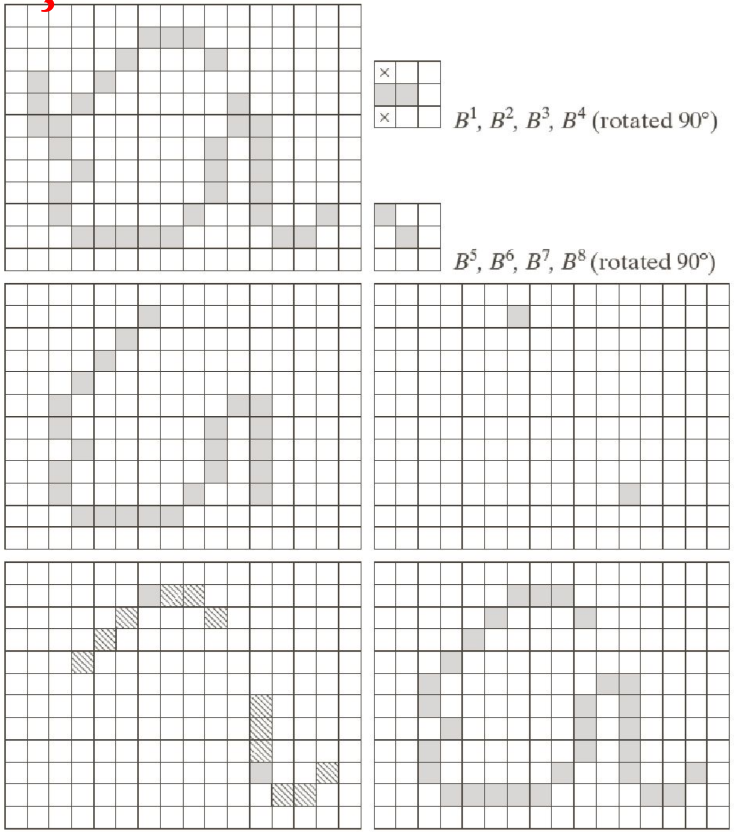


FIGURE 9.24 Implementation of Eqs. (9.5-11) through (9.5-15). The original set is at the top left, and its morphological skeleton is at the bottom of the fourth column. The reconstructed set is at the bottom of the sixth column.

Budama İşlemi



a b
c
d e
f g

FIGURE 9.25 (a) Original image. (b) and (c) Structuring elements used for deleting end points. (d) Result of three cycles of thinning. (e) End points of (d). (f) Dilation of end points conditioned on (a). (g) Pruned image.

İnceltme işlemi üç defa tekrarlanıyor

Geodezik Genişleme

Klasik genişleme sonucunun bir maske görüntüsü ile kesişimi alınır.

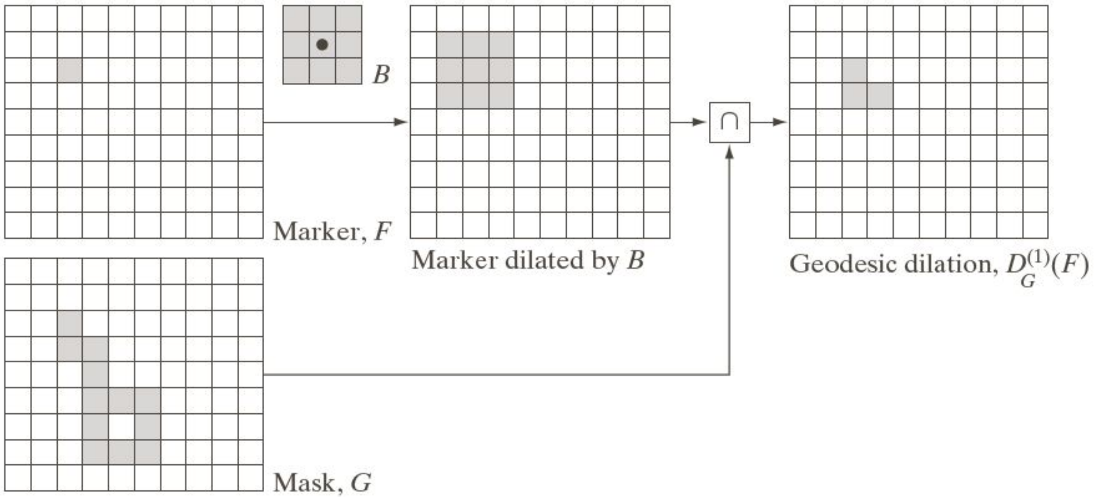


FIGURE 9.26 Illustration of geodesic dilation.

Geodezik Aşınma

Klasik aşınma sonucunun bir maske görüntüsü ile birleşimi alınır.

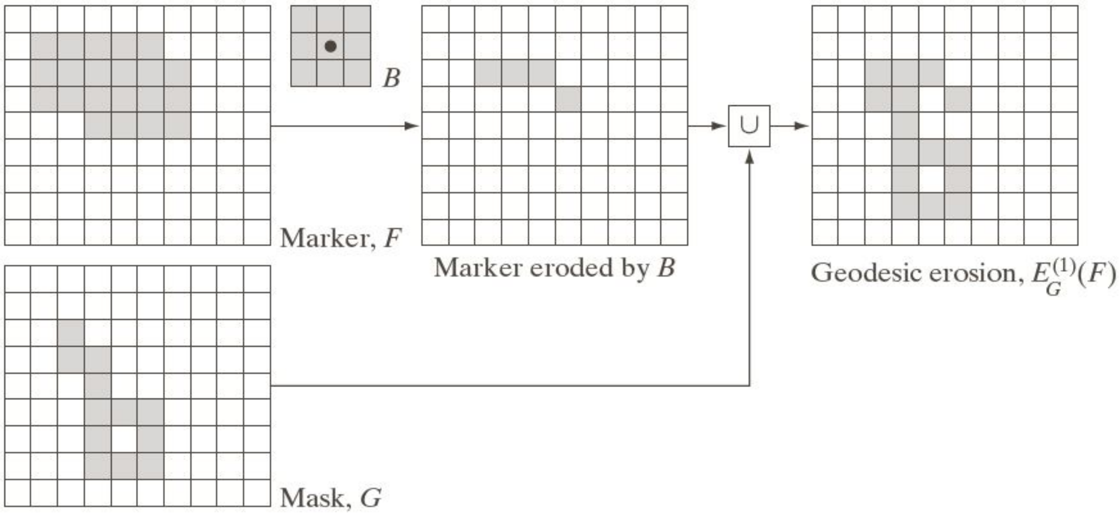
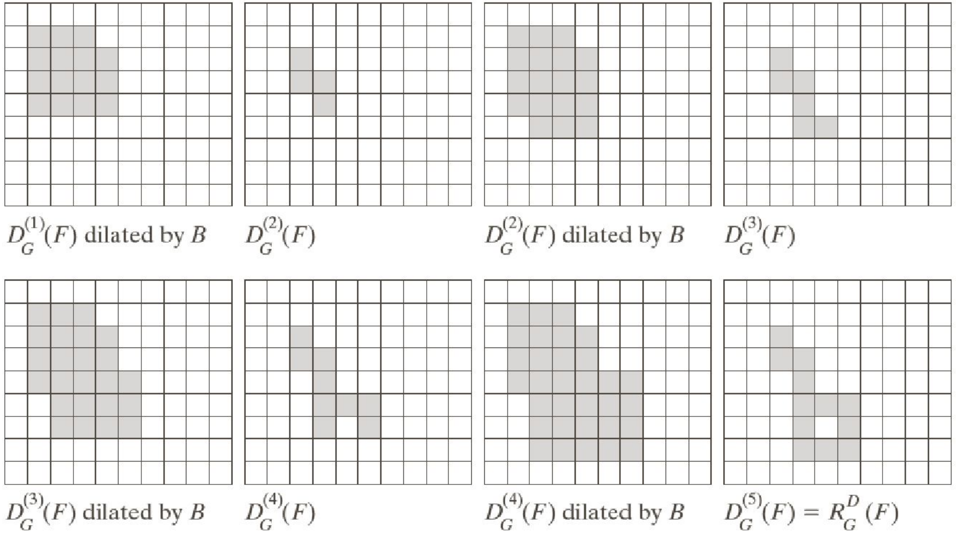


FIGURE 9.27 Illustration of geodesic erosion.

Genişleme ile inşa (tamir)

Bu slaytta genişleme kullanılarak nesnenin adım adım inşası anlatılmakta.

$D^{(k)}$ sonucu G ile AND işlemine tabi tutulunca $D^{(k+1)}$ elde ediliyor



a	b	c	d
e	f	g	h

FIGURE 9.28 Illustration of morphological reconstruction by dilation. F, G, B and $D_G^{(1)}(F)$ are from Fig. 9.26.

Açma işlemi ile inşa (tamir) etme
Opening by Reconstruction

Klasik açma işlemi aşınma ve genişlemeyi içerir. Aşınma gürültüyü temizler, genişleme nesneyi tamir eder. Fakat tamir başarısı kullanılan SE ye ve nesne şekline çok bağlıdır.

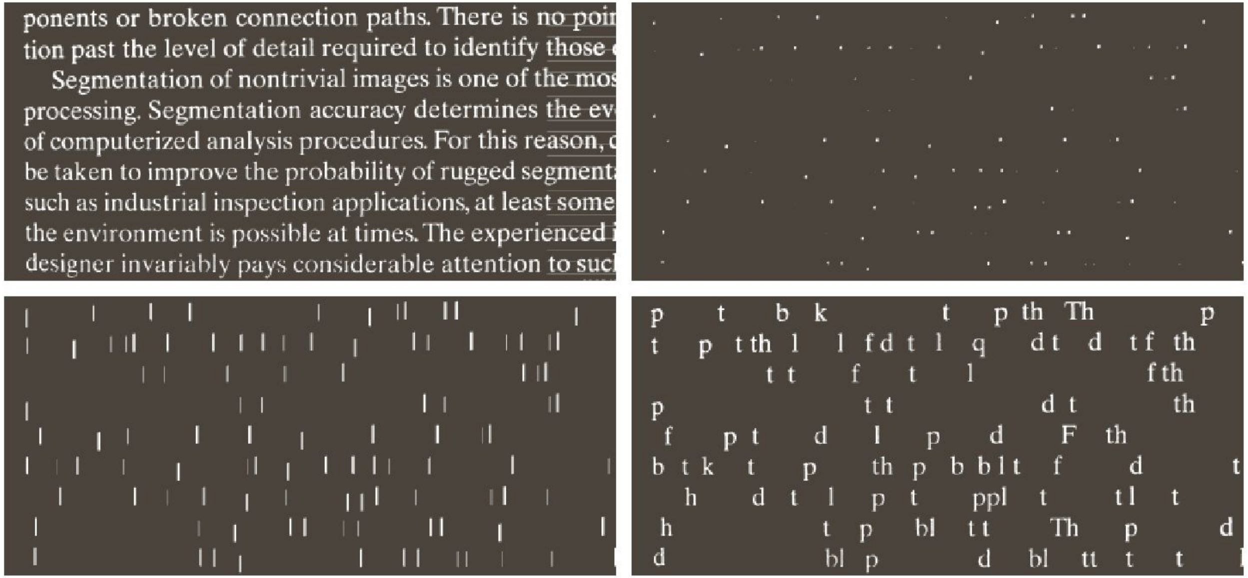
Bunun yanında **açma ile tamir işlemi**, aşınmadan sonra kalan nesnelerin şekillerini tam tamir eder. Bu işlemde önce aşınma, sonra genişleme kullanıldığı için bu adı almıştır. $\boldsymbol{F}$ imgesinin $\boldsymbol{n}$ boyutlu **açma ile tamir işlemi** aşağıdaki gibi tanımlanır:

$$O_R^{(n)}(F) = R_F^D[(F \ominus nB)]$$

$(\boldsymbol{F} \ominus \boldsymbol{nB})$ işlemi $\boldsymbol{F}$ imgesinin $\boldsymbol{n}$ defa $\boldsymbol{B}$ maskesiyle aşınması anlamına gelir. Bu aşamadan sonra orijinal $\boldsymbol{F}$ imgesi maske olarak kullanılır ve aşınmış imgenin **genişleme ile inşa** işlemi başlar. Bu işlem bir önceki slayt'ta anlatılmaktadır.

Örnek - Açma işlemi ile inşa etme

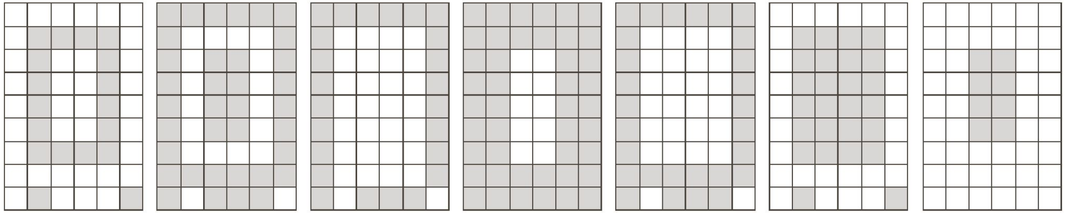
Bu örnekte yukarıdan aşağıya uzun çizgiye sahip karakterler tespit edilmektedir. $\boldsymbol{F}$ imgesi maske olarak kullanılmaktadır. $\boldsymbol{n} = \mathbf{1}$ dir. Bu nedenle sadece bir defa aşınma yapılmıştır.



a b
c d

FIGURE 9.29 (a) Text image of size 918 × 2018 pixels. The approximate average height of the tall characters is 50 pixels. (b) Erosion of (a) with a structuring element of size 51 × 1 pixels. (c) Opening of (a) with the same structuring element, shown for reference. (d) Result of opening by reconstruction.

Delik doldurma (Yöntem-2)



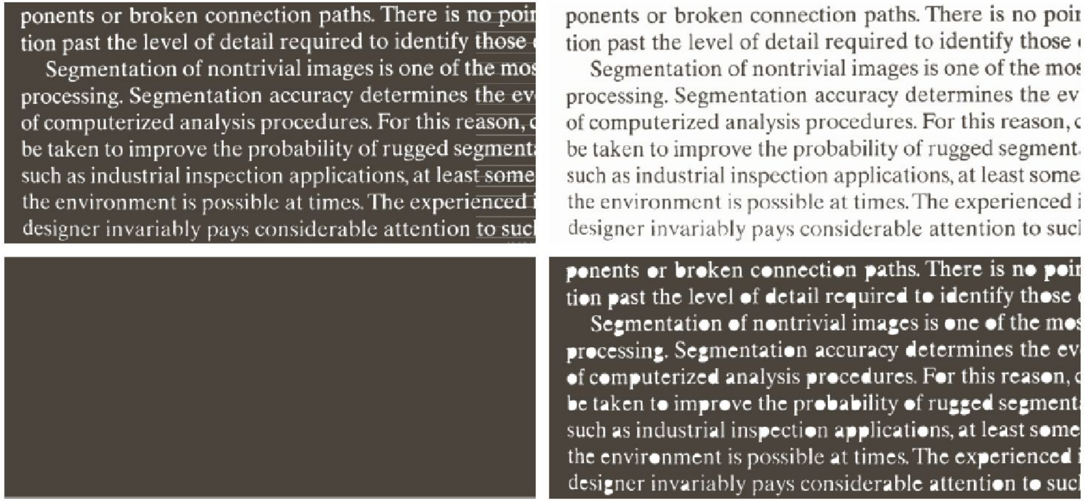
a b c d e f g

FIGURE 9.30 Illustration of hole filling on a simple image.

$$F(x, y) = \begin{cases} 1 - I(x, y) & \text{if}(x, y)\text{is on the border of I} \\ 0 & \text{otherwise} \end{cases}$$

$$H = [R^D_{I^c}(F)]^c$$

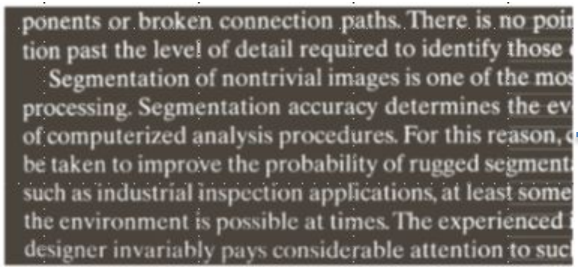
Örnek - Delik doldurma (Yöntem-2)



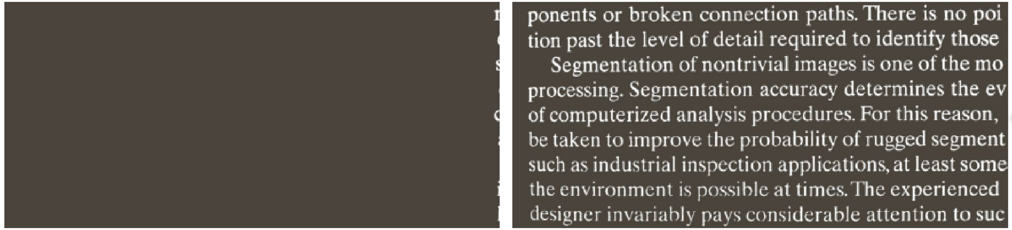
a b
c d

FIGURE 9.31
(a) Text image of size 918 × 2018 pixels. (b) Complement of (a) for use as a mask image. (c) Marker image. (d) Result of hole-filling using Eq. (9.5-29).

Örnek - Sınır Temizleme


ponents or broken connection paths. There is no poi
tion past the level of detail required to identify those
Segmentation of nontrivial images is one of the mos
processing. Segmentation accuracy determines the ev
of computerized analysis procedures. For this reason,
be taken to improve the probability of rugged segment
such as industrial inspection applications, at least some
the environment is possible at times. The experienced
designer invariably pays considerable attention to suc

I


ponents or broken connection paths. There is no poi
tion past the level of detail required to identify those
Segmentation of nontrivial images is one of the mo
processing. Segmentation accuracy determines the ev
of computerized analysis procedures. For this reason,
be taken to improve the probability of rugged segment
such as industrial inspection applications, at least some
the environment is possible at times. The experienced
designer invariably pays considerable attention to suc

X

a b

FIGURE 9.32 Border clearing. (a) Marker image. (b) Image with no objects touching the border. The original image is Fig. 9.29(a).

$R^D(F)$ ➔ Sınır piksellerinin genişletilmiş hali

$$F(x,y) = \begin{cases} 1 - I(x,y) & \text{if}(x,y) \text{is on the border of I} \\ 0 & \text{otherwise} \end{cases}$$

Sınır pikselleri

$$X = I - R_I^D(F)$$

En sık kullanılan beş yapısal element tipi

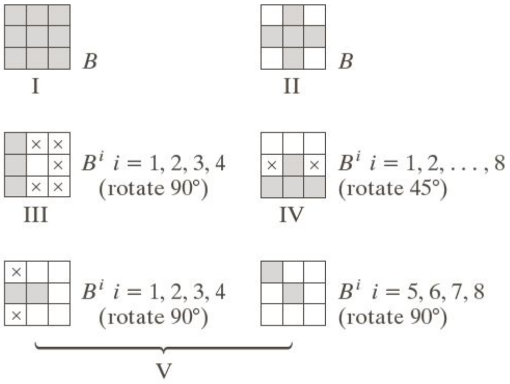


FIGURE 9.33 Five basic types of structuring elements used for binary morphology. The origin of each element is at its center and the ×'s indicate "don't care" values.

Özet Tablo

Operation	Equation	Comments (The Roman numerals refer to the structuring elements in Fig. 9.33.)
Translation	$(B)_z = \{w \mid w = b + z, \text{ for } b \in B\}$	Translates the origin of B to point z.
Reflection	$\hat{B} = \{w \mid w = -b, \quad \text{for } b \in B\}$	Reflects all elements of B about the origin of this set.
Complement	$A^c = \{w \mid w \notin A\}$	Set of points not in A.
Difference	$A - B = \{w \mid w \in A, w \notin B\} = A \cap B^c$	Set of points that belong to A but not to B.
Dilation	$A \oplus B = \left\{z \mid (\hat{B}_z) \cap A \neq \varnothing\right\}$	"Expands" the boundary of A. (I)
Erosion	$A \ominus B = \left\{z \mid (B)_z \subseteq A\right\}$	"Contracts" the boundary of A. (I)
Opening	$A \circ B = (A \ominus B) \oplus B$	Smoothes contours, breaks narrow isthmuses, and eliminates small islands and sharp peaks. (I)

(Continued)

TABLE 9.1 Summary of morphological operations and their properties.

Özet Tablo

Operation	Equation	Comments (The Roman numerals refer to the structuring elements in Fig. 9.33.)
Closing	$A \bullet B = (A \oplus B) \ominus B$	Smoothes contours, fuses narrow breaks and long thin gulfs, and eliminates small holes. (I)
Hit-or-miss transform	$A \circledast B = (A \ominus B_1) \cap (A^c \ominus B_2) = (A \ominus B_1) - (A \oplus \hat{B}_2)$	The set of points (coordinates) at which, simultaneously, B_1 found a match ("hit") in A and B_2 found a match in A^c
Boundary extraction	$\beta(A) = A - (A \ominus B)$	Set of points on the boundary of set A. (I)
Hole filling	$X_k = (X_{k-1} \oplus B) \cap A^c$; $k = 1, 2, 3, \ldots$	Fills holes in A; $X_0 =$ array of 0s with a 1 in each hole. (II)
Connected components	$X_k = (X_{k-1} \oplus B) \cap A$; $k = 1, 2, 3, \ldots$	Finds connected components in A; $X_0 =$ array of 0s with a 1 in each connected component. (I)
Convex hull	$X_k^i = (X_{k-1}^i \circledast B^i) \cup A$; $i = 1, 2, 3, 4$; $k = 1, 2, 3, \ldots$; $X_0^i = A$; and $D^i = X_{\text{conv}}^i$	Finds the convex hull $C(A)$ of set A, where "conv" indicates convergence in the sense that $X_k^i = X_{k-1}^i$. (III)
Thinning	$A \otimes B = A - (A \circledast B) = A \cap (A \circledast B)^c$; $A \otimes \{B\} = ((\ldots((A \otimes B^1) \otimes B^2) \ldots) \otimes B^n)$; $\{B\} = \{B^1, B^2, B^3, \ldots, B^n\}$	Thins set A. The first two equations give the basic definition of thinning. The last equations denote thinning by a sequence of structuring elements. This method is normally used in practice. (IV)
Thickening	$A \odot B = A \cup (A \circledast B)$; $A \odot \{B\} = ((\ldots(A \odot B^1) \odot B^2 \ldots) \odot B^n)$	Thickens set A. (See preceding comments on sequences of structuring elements.) Uses IV with 0s and 1s reversed.
Skeletons	$S(A) = \bigcup_{k=0}^{K} S_k(A)$; $S_k(A) = \bigcup_{k=0}^{K} \{(A \ominus kB) - [(A \ominus kB) \circ B]\}$; Reconstruction of A: $A = \bigcup_{k=0}^{K} (S_k(A) \oplus kB)$	Finds the skeleton $S(A)$ of set A. The last equation indicates that A can be reconstructed from its skeleton subsets $S_k(A)$. In all three equations, K is the value of the iterative step after which the set A erodes to the empty set. The notation $(A \ominus kB)$ denotes the kth iteration of successive erosions of A by B. (I)

(Continued)

TABLE 9.1
(Continued)

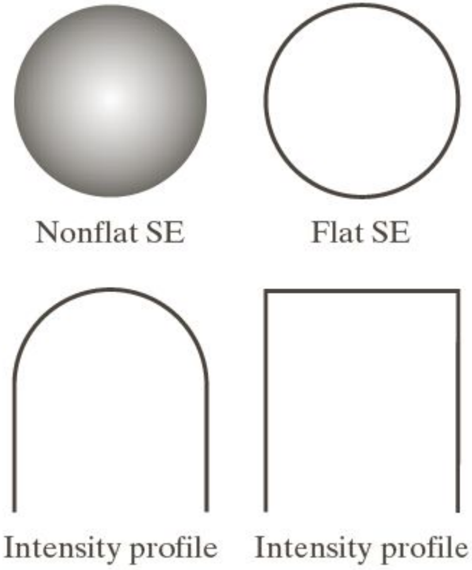
Özet Tablo

TABLE 9.1
(Continued)

Operation	Equation	Comments (The Roman numerals refer to the structuring elements in Fig. 9.33.)
Pruning	$X_1 = A \otimes \{B\}$ $X_2 = \bigcup_{k=1}^{8} (X_1 \circledast B^k)$ $X_3 = (X_2 \oplus H) \cap A$ $X_4 = X_1 \cup X_3$	X_4 is the result of pruning set A. The number of times that the first equation is applied to obtain X_1 must be specified. Structuring elements V are used for the first two equations. In the third equation H denotes structuring element I.
Geodesic dilation of size 1	$D_G^{(1)}(F) = (F \oplus B) \cap G$	F and G are called the *marker* and *mask* images, respectively.
Geodesic dilation of size n	$D_G^{(n)}(F) = D_G^{(1)}\left[D_G^{(n-1)}(F)\right]$; $D_G^{(0)}(F) = F$	
Geodesic erosion of size 1	$E_G^{(1)}(F) = (F \ominus B) \cup G$	
Geodesic erosion of size n	$E_G^{(n)}(F) = E_G^{(1)}\left[E_G^{(n-1)}(F)\right]$; $E_G^{(0)}(F) = F$	
Morphological reconstruction by dilation	$R_G^D(F) = D_G^{(k)}(F)$	k is such that $D_G^{(k)}(F) = D_G^{(k+1)}(F)$
Morphological reconstruction by erosion	$R_G^E(F) = E_G^{(k)}(F)$	k is such that $E_G^{(k)}(F) = E_G^{(k+1)}(F)$
Opening by reconstruction	$O_R^{(n)}(F) = R_F^D[(F \ominus nB)]$	$(F \ominus nB)$ indicates n erosions of F by B.
Closing by reconstruction	$C_R^{(n)}(F) = R_F^E[(F \oplus nB)]$	$(F \oplus nB)$ indicates n dilations of F by B.
Hole filling	$H = \left[R_{I^c}^D(F)\right]^c$	H is equal to the input image I, but with all holes filled. See Eq. (9.5-28) for the definition of the marker image F.
Border clearing	$X = I - R_I^D(F)$	X is equal to the input image I, but with all objects that touch (are connected to) the boundary removed. See Eq. (9.5-30) for the definition of the marker image F.

Gri Seviyede Morfolojik İşlemler

Yapısal Element



a b
c d

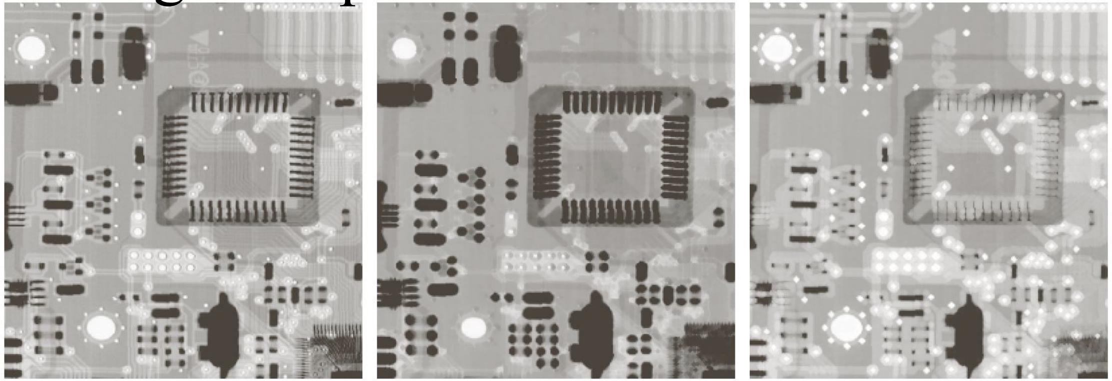
FIGURE 9.34 Nonflat and flat structuring elements, and corresponding horizontal intensity profiles through their center. All examples in this section are based on flat SEs.

Gri seviyedeki bu yapısal elementler pratikte çok kullanılmaz.
Bunun nedeni ileriki bölümlerde bahsedilecek dezavantajlara sahip olmasıdır.

Gri Seviyede Aşınma ve Genişleme

Aşınma: Konvolüsyon sonucunun minimumu alınır. İmge koyulaşır.

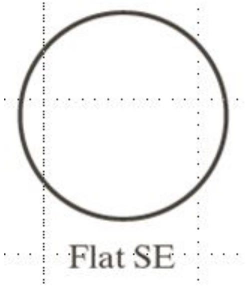
Genişleme: Konvolüsyon sonucunun maksimumu alınır. İmgedeki parlaklık artar.



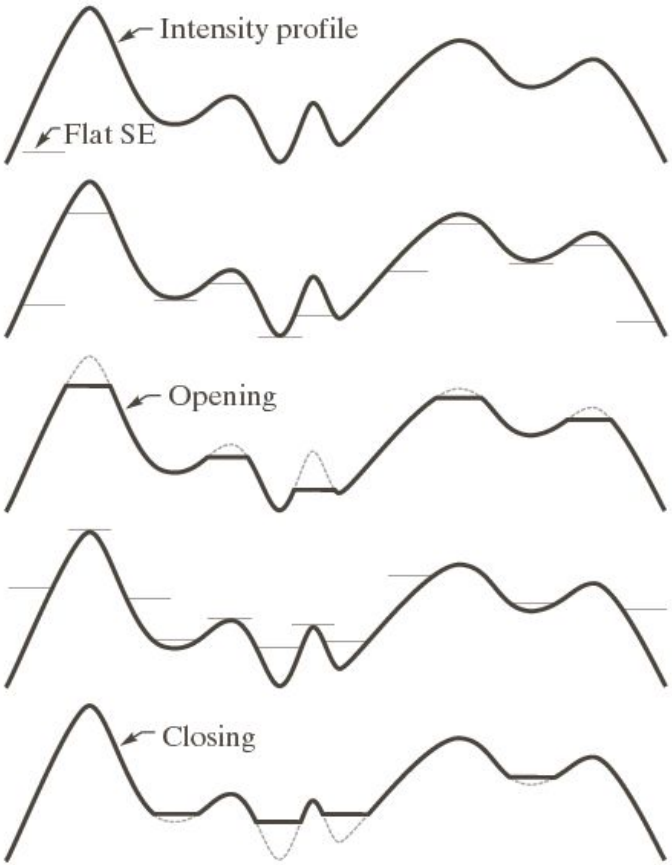
a b c

FIGURE 9.35 (a) A gray-scale X-ray image of size 448 × 425 pixels. (b) Erosion using a flat disk SE with a radius of two pixels. (c) Dilation using the same SE. (Original image courtesy of Lixi, Inc.)

Kullanılan SE



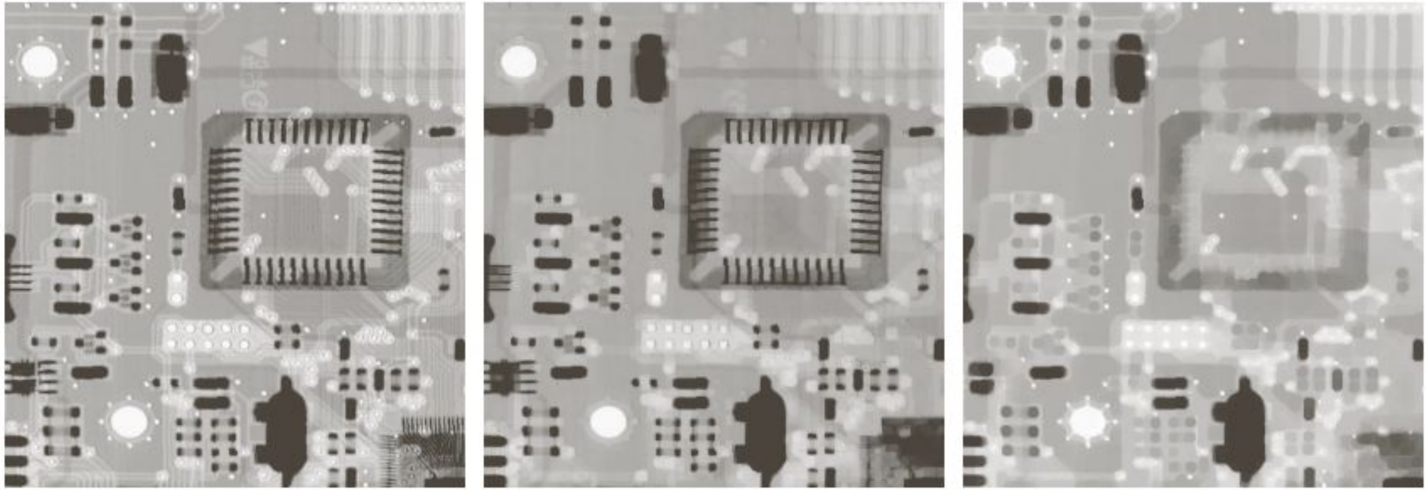
Gri Seviyede Açma ve Kapama



a
b
c
d
e

FIGURE 9.36 Opening and closing in one dimension. (a) Original 1-D signal. (b) Flat structuring element pushed up underneath the signal. (c) Opening. (d) Flat structuring element pushed down along the top of the signal. (e) Closing.

Gri Seviyede Açma ve Kapama Örneği

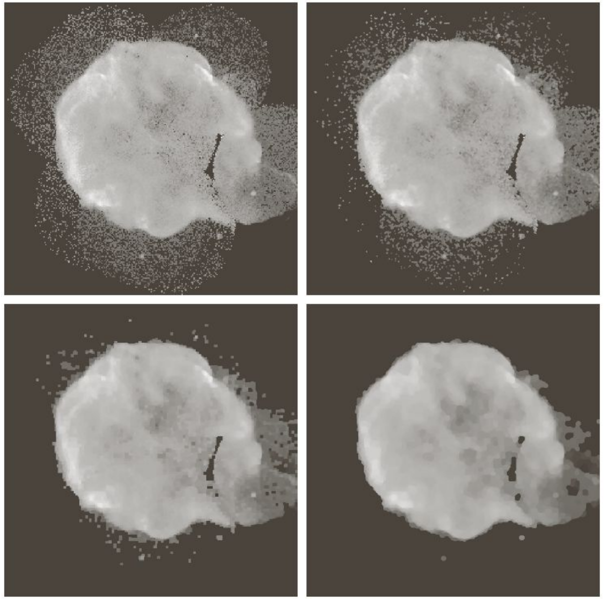


a b c

FIGURE 9.37 (a) A gray-scale X-ray image of size 448 × 425 pixels. (b) Opening using a disk SE with a radius of 3 pixels. (c) Closing using an SE of radius 5.

Uygulama1 - Gri Seviyede Gürültü Eleme

Açma ve Kapama işlemleri ardışık kullanılarak gürültü elenebilir.



a b
c d

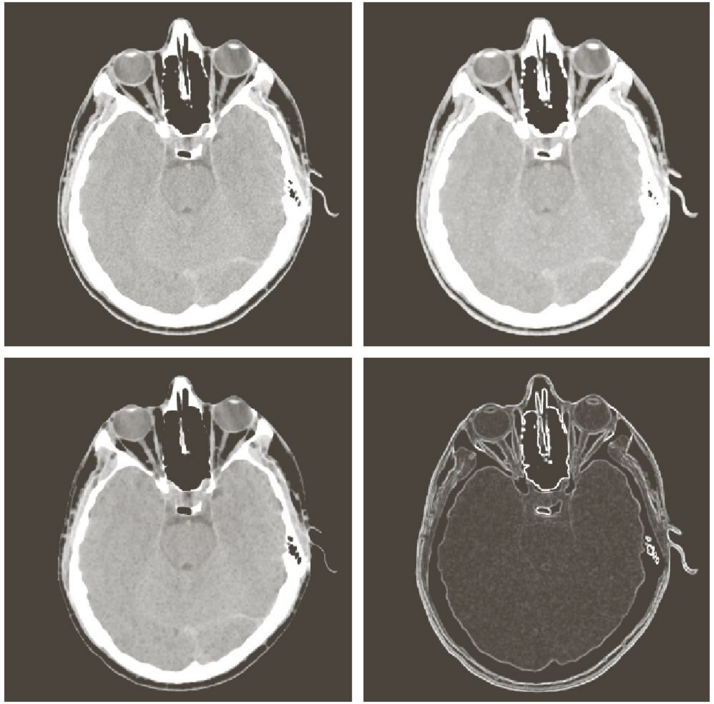
FIGURE 9.38
(a) 566 × 566 image of the Cygnus Loop supernova, taken in the X-ray band by NASA's Hubble Telescope. (b)–(d) Results of performing opening and closing sequences on the original image with disk structuring elements of radii, 1, 3, and 5, respectively. (Original image courtesy of NASA.)

SE nin yarıçapları

Uygulama2 - Morfolojik Gradient

Gradient, genişleme ile aşınmanın farkı olarak hesaplanabilir.

$$g = (f \oplus b) - (f \ominus b)$$



a b
c d

FIGURE 9.39 (a) 512 × 512 image of a head CT scan. (b) Dilation. (c) Erosion. (d) Morphological gradient, computed as the difference between (b) and (c). (Original image courtesy of Dr. David R. Pickens, Vanderbilt University.)

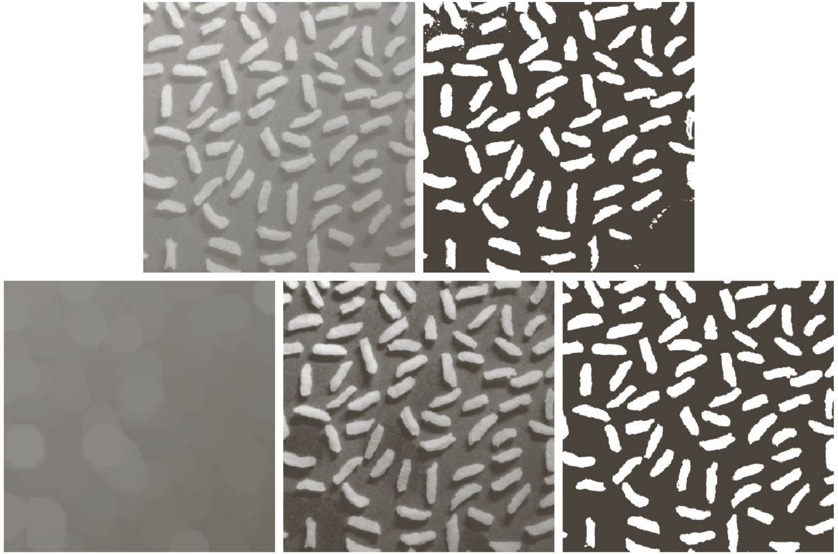
Uygulama3 - Top-Hat ve Bottom-Hat Dönüşümler

Uniform olmayan ışık etkilerinin düzeltilmesinde kullanılır.

Ayrıca yapısal elemente uymayan şekillerde yok edilir.

Top-Hat : $T_{hat}(f) = f - (f \circ b)$

Bottom-Hat : $B_{hat}(f) = (f \text{¥} b) - f$



a b
c d e

FIGURE 9.40 Using the top-hat transformation for *shading correction*. (a) Original image of size 600 × 600 pixels. (b) Thresholded image. (c) Image opened using a disk SE of radius 40. (d) Top-hat transformation (the image minus its opening). (e) Thresholded top-hat image.

Uygulama4 - Granulometry

Granulometry, görüntüdeki parçacık dağılımının boyutunu hesaplanma anlamına gelir. Düzenli bir şekle sahip parçacıklar Opening işlemi ile elenip arka plan ortaya çıkarılır. Ayrıca bu yöntemle defolu parçacıkların tespiti de yapılır.

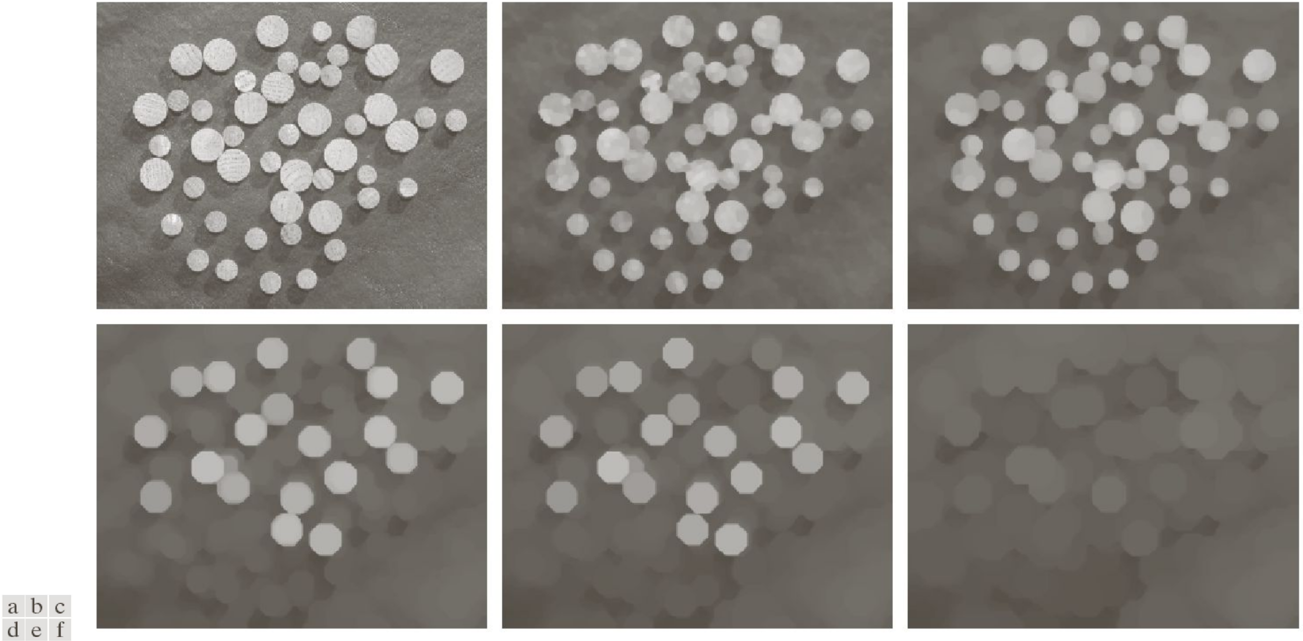


FIGURE 9.41 (a) 531 × 675 image of wood dowels. (b) Smoothed image. (c)–(f) Openings of (b) with disks of radii equal to 10, 20, 25, and 30 pixels, respectively. (Original image courtesy of Dr. Steve Eddins, The MathWorks, Inc.)

Uygulama4 - Granulometry

Aşağıdaki grafik önceki slaytaki görüntünün farklı yarıçaplı SE ler kullanılarak opening yapılması ve sonuç imgesinin gradyan toplamının hesaplanmasıyla elde edilmiştir. Dikkat edilirse, iki çap değerinde gradyan (farklılık) değeri aşırı tırmanış (zirve) göstermiştir. Bu sonuç, görüntünün iki baskın çaplı şekiller içerdiğini göstermektedir.

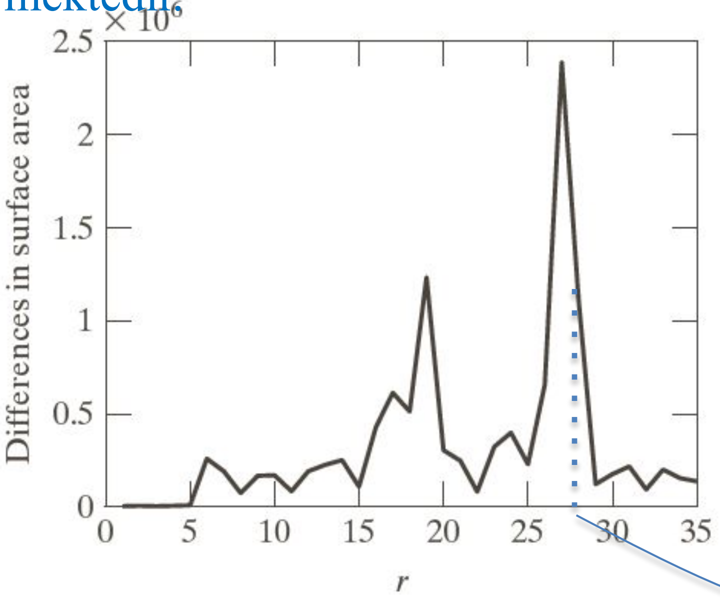
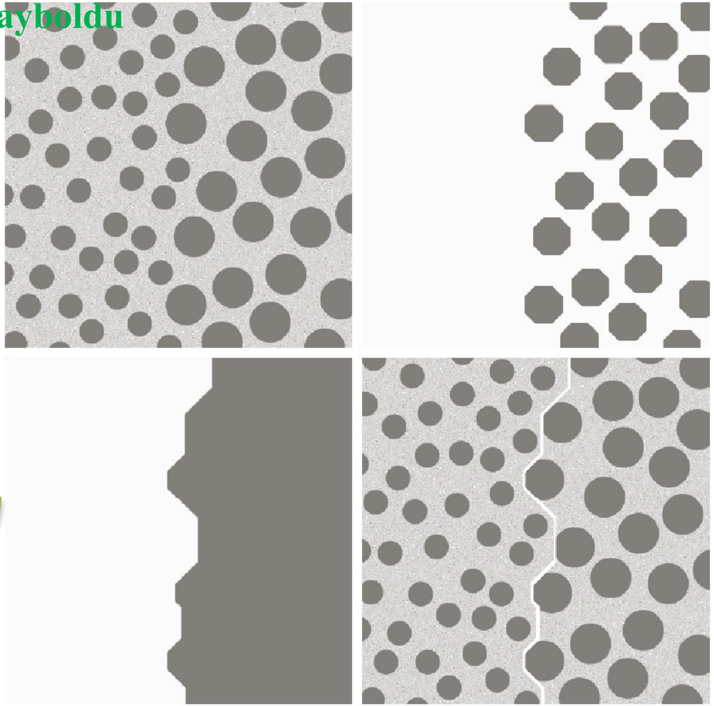


FIGURE 9.42 Differences in surface area as a function of SE disk radius, r. The two peaks are indicative of two dominant particle sizes in the image.

İmge, çoğunlukla bu çaplara sahip şekilleri içermektedir.

Uygulama5 - Yapısal Bölümleme

Ön plan beyaz, arka plan siyah delikler olduğu için kapatma (closing) sonucunda beyaz alanlar genişleyerek küçük şekiller kayboldu



a b
c d

FIGURE 9.43 Textural segmentation. (a) A 600 × 600 image consisting of two types of blobs. (b) Image with small blobs removed by closing (a). (c) Image with light patches between large blobs removed by opening (b). (d) Original image with boundary between the two regions in (c) superimposed. The boundary was obtained using a morphological gradient operation.

Siyah delikler arasına sığmayacak büyüklükte bir SE seçilip açma (opening) yapıldı

Gri Seviyede Morfolojik İnşa

Geodezik Genişleme:

b yapısal element, f ve g boyutları aynı olan marker ve maske imgeleri olsun. f imgesinin 1 boyutlu geodezik genişleme işlemi aşağıdaki gibi ifade edilir:

$$D_g^{(1)}(f) = (f \oplus b) \wedge g$$

$\wedge$ işlemi point-wise minimumu ifade eder. Bu işlemin n boyutlusu:

$$D_g^{(n)}(f) = D^{(1)}[D_g^{(n-1)}(f)] \qquad D_g^{(0)}(f) = f$$

Geodezik Aşınma:

$$E_g^{(1)}(f) = (f \ominus b) \vee g$$

$\vee$işlemi point-wise maksimumu ifade eder. Bu işlemin n boyutlusu:

$$E_g^{(n)}(f) = E_g^{(1)}[E_g^{(n-1)}(f)] \qquad E_g^{(0)}(f) = f$$

Gri Seviyede Morfolojik İnşa

Genişleme ile inşa:

g: Gri seviye maske görüntüsü
f: Gri seviye marker görüntüsü
Genişleme ile morfolojik inşa işlemi aşağıdaki gibi tanımlanır:

$$R_g^D(f) = D_g^{(k)}(f)$$

k değeri $D_g^{(k)}(f) = D_g^{(k+1)}(f)$ eşitliği sağlandığında ortaya çıkar.

Aşınma ile inşa:

Aşınma ile morfolojik inşa işlemi aşağıdaki gibi tanımlanır:

$$R_g^E(f) = E_g^{(k)}(f)$$

k değeri $E_g^{(k)}(f) = E_g^{(k+1)}(f)$ eşitliği sağlandığında ortaya çıkar.

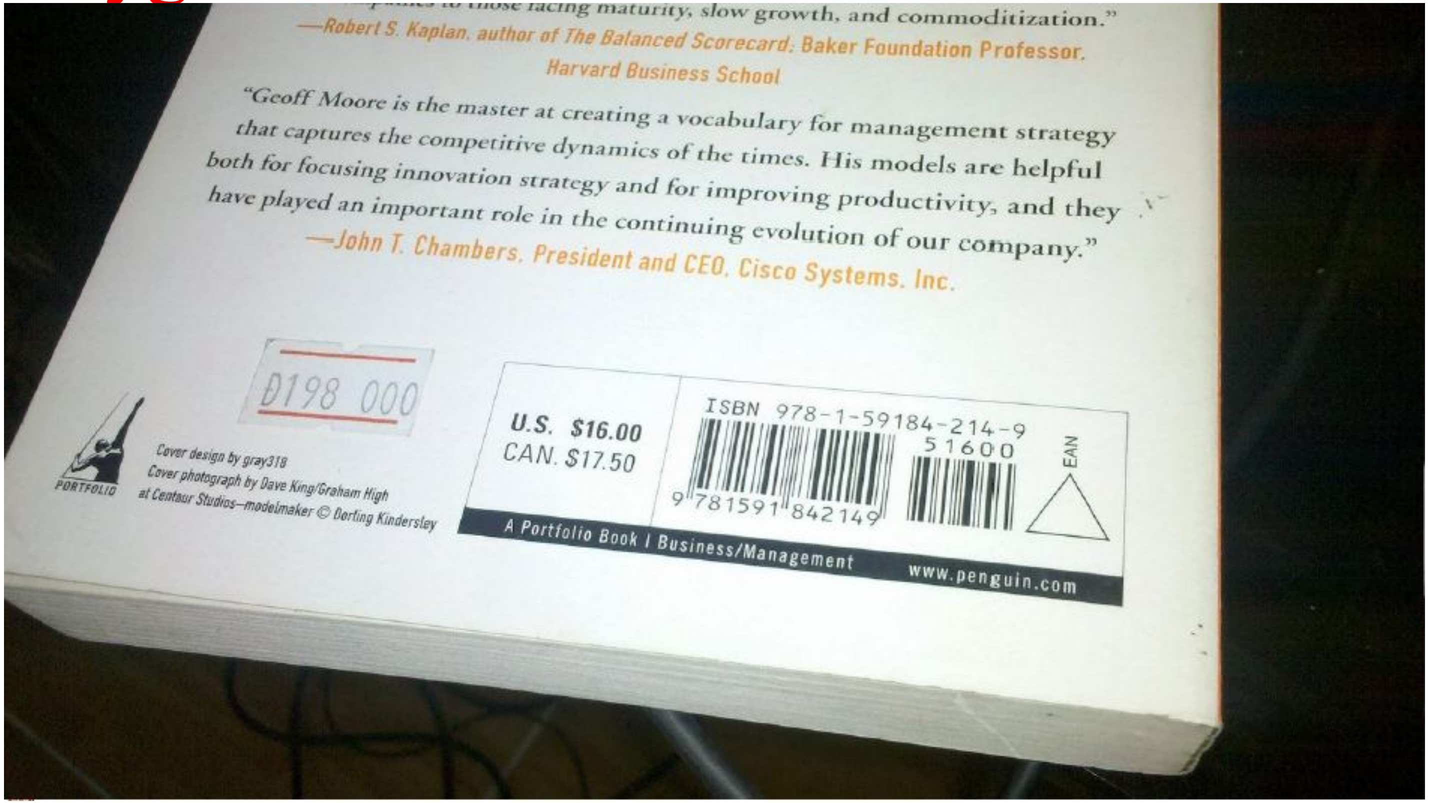
Açma ile inşa:

$$O_R^{(n)}(f) = R_f^D[(f \ominus nb)]$$

$$C_R^{(n)}(f) = R_f^E[(f \oplus nb)]$$

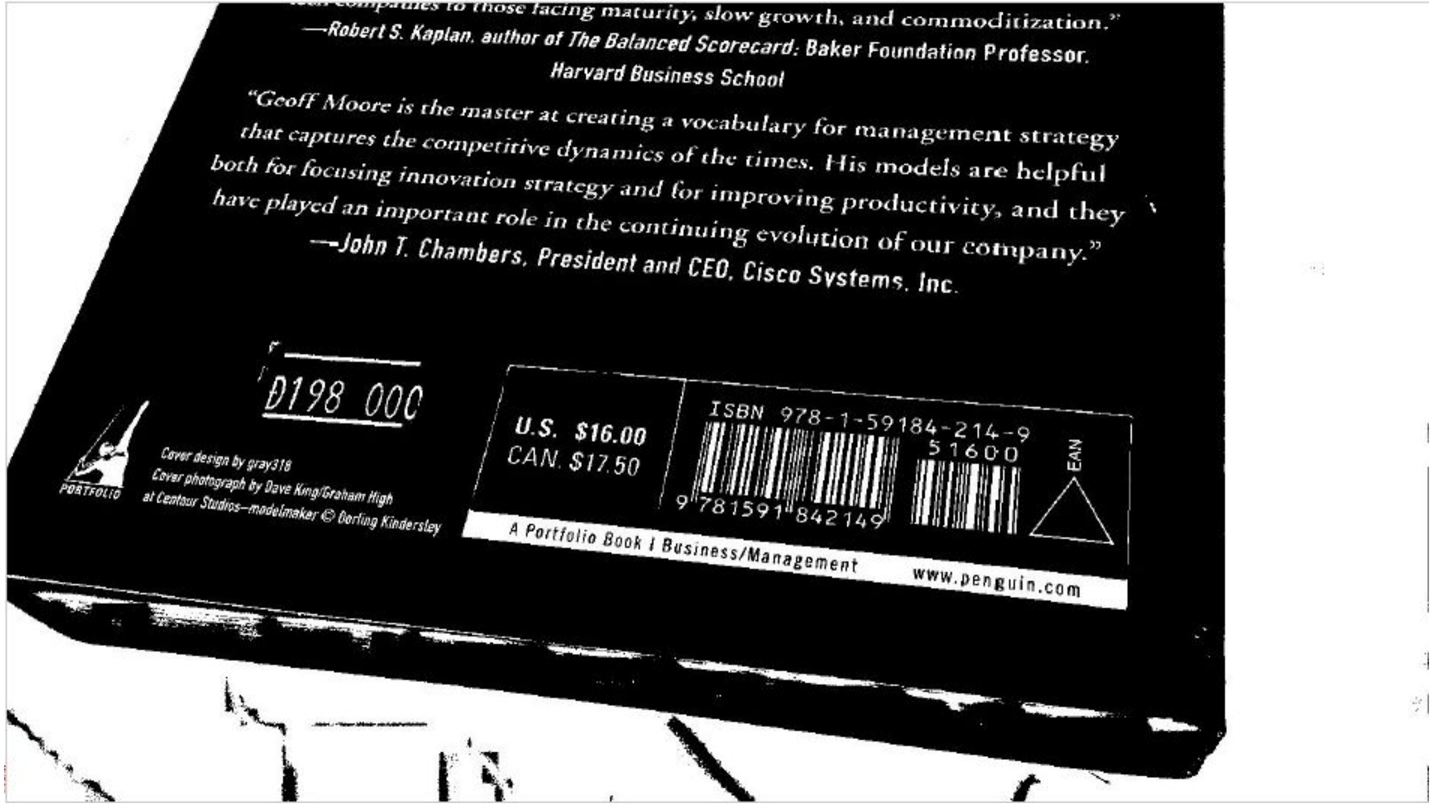
Kapanma ile inşa:

Uygulama6 – BarCode Yakalama



Uygulama6 – BarCode Yakalama

Locally adaptive binarization

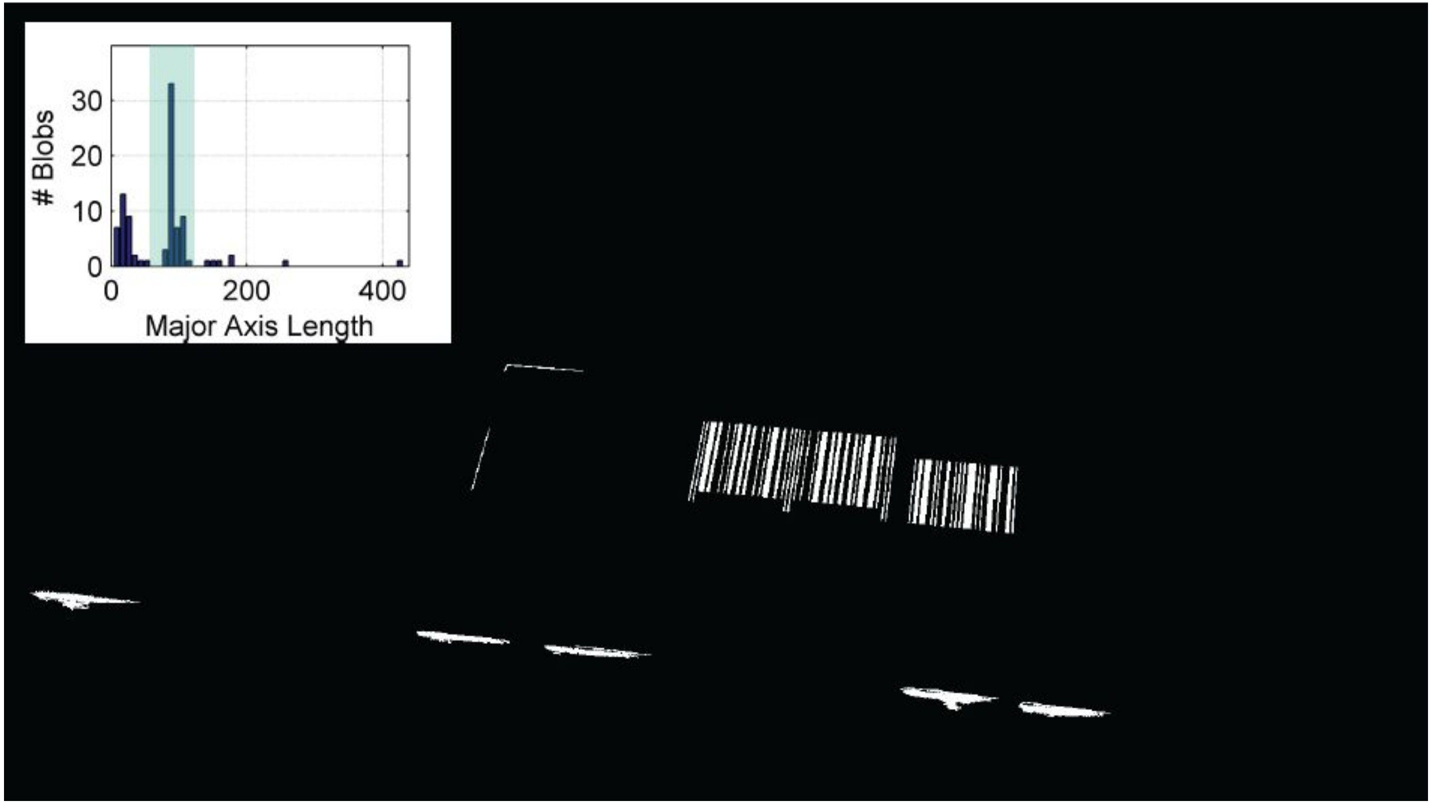


Uygulama6 – BarCode Yakalama

Locally adaptive binarization → Filtering by eccentricity

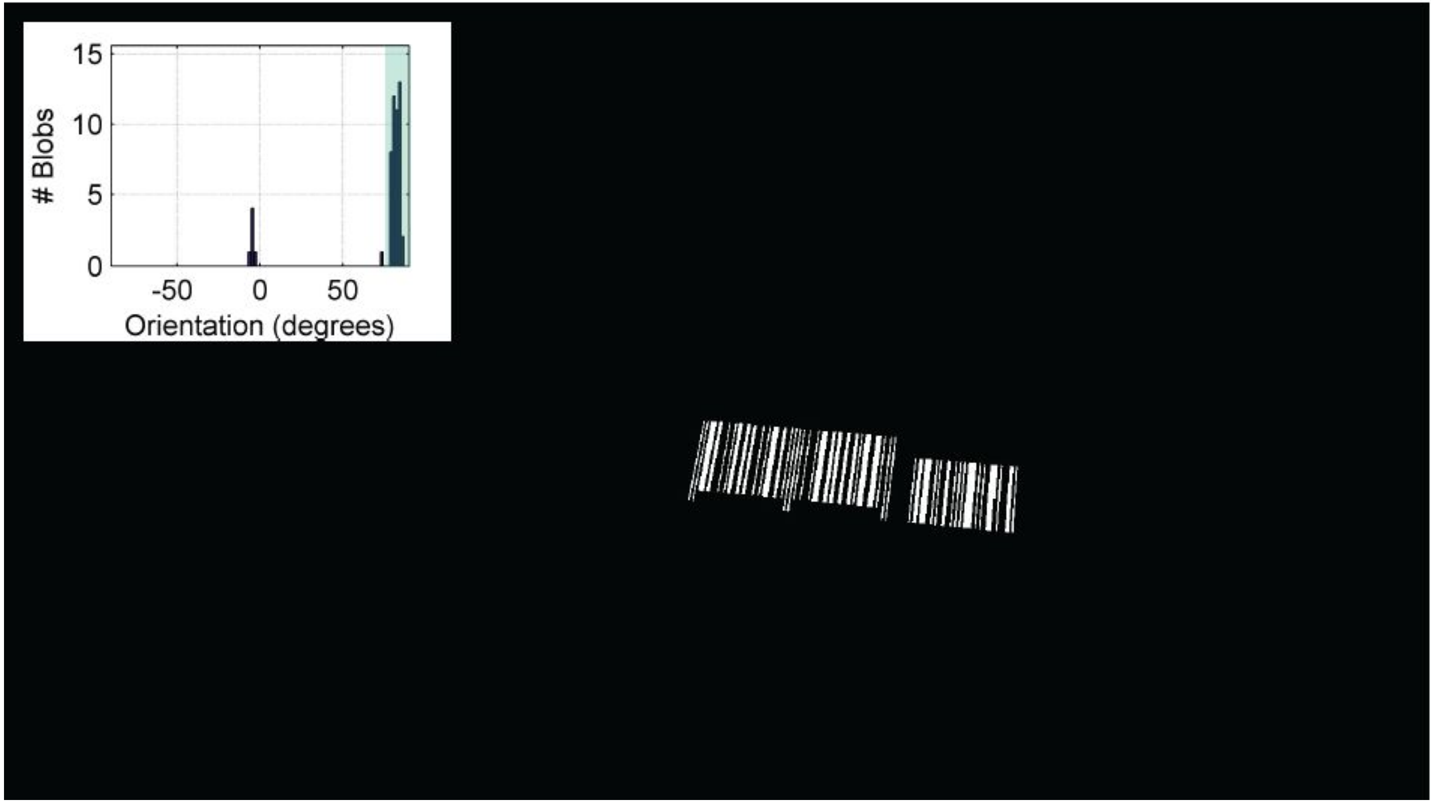
Uygulama6 – BarCode Yakalama

Locally adaptive binarization → Filtering by eccentricity → Filtering by major axis length



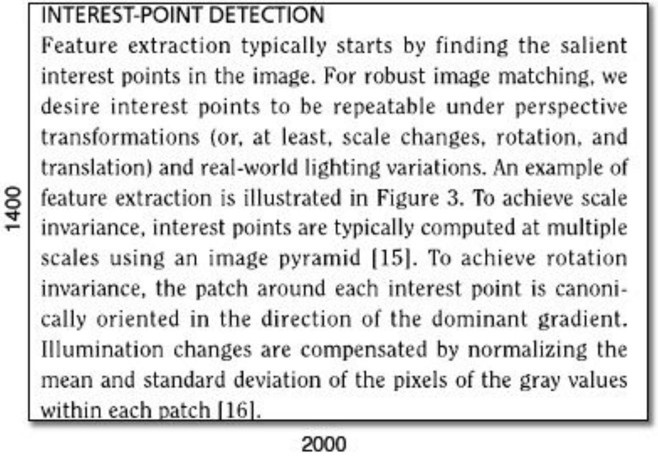
Uygulama6 – BarCode Yakalama

Locally adaptive binarization → Filtering by eccentricity → Filtering by major axis length → Filtering by orientation

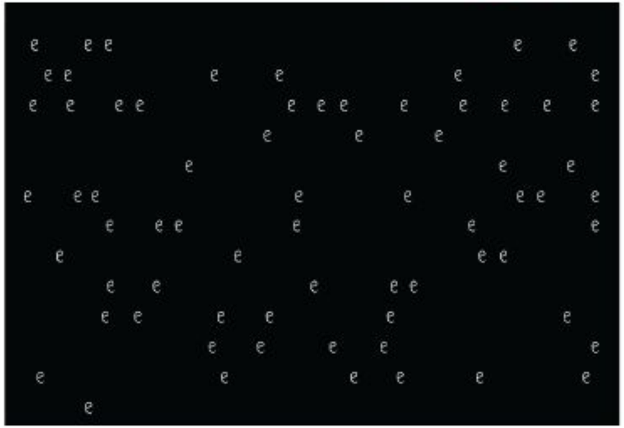


Uygulama7 –e Karakterini Yakalama

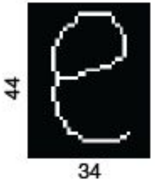
Binary image f



$$open\left(NOT[f],W\right) = dilate\left(erode\left(NOT[f],W\right),W\right)$$



Structuring element W

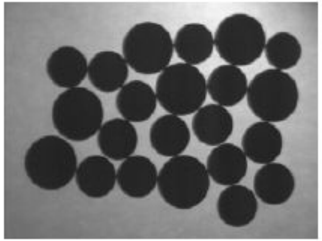


Uygulama7 –e Karakterini Yakalama

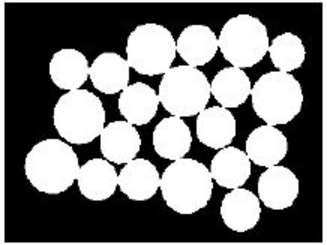
INTEREST-POINT DETECTION

Feature extraction typically starts by finding the salient interest points in the image. For robust image matching, we desire interest points to be repeatable under perspective transformations (or, at least, scale changes, rotation, and translation) and real-world lighting variations. An example of feature extraction is illustrated in Figure 3. To achieve scale invariance, interest points are typically computed at multiple scales using an image pyramid [15]. To achieve rotation invariance, the patch around each interest point is canonically oriented in the direction of the dominant gradient. Illumination changes are compensated by normalizing the mean and standard deviation of the pixels of the gray values within each patch [16].

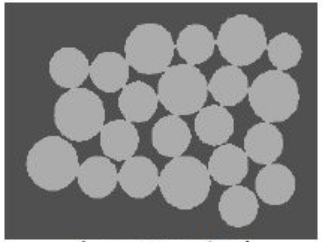
Uygulama8 –Sayma



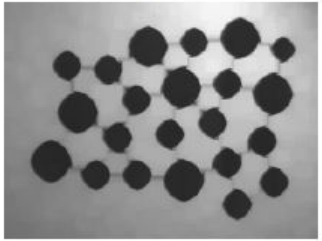
Original



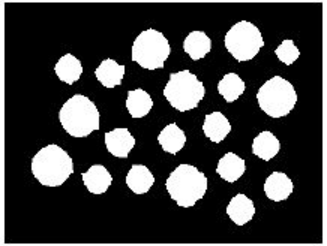
thresholded



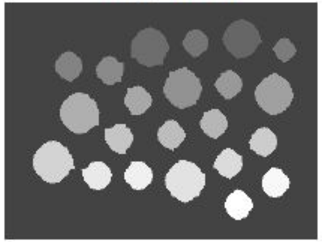
1 connected component



dilation



thresholded after dilation



22 connected components

Uygulama9 –Karakteri Yakalama

a b c
d e f
g h i

FIGURE 9.44 (a) Original image of size 1134 × 1360 pixels. (b) Opening by reconstruction of (a) using a horizontal line 71 pixels long in the erosion. (c) Opening of (a) using the same line. (d) Top-hat by reconstruction. (e) Top-hat. (f) Opening by reconstruction of (d) using a horizontal line 11 pixels long. (g) Dilation of (f) using a horizontal line 21 pixels long. (h) Minimum of (d) and (g). (i) Final reconstruction result. (Images courtesy of Dr. Steve Eddins, The MathWorks, Inc.)