# Digital Image Processing

## Chapter 4
## Morphological Image Processing B

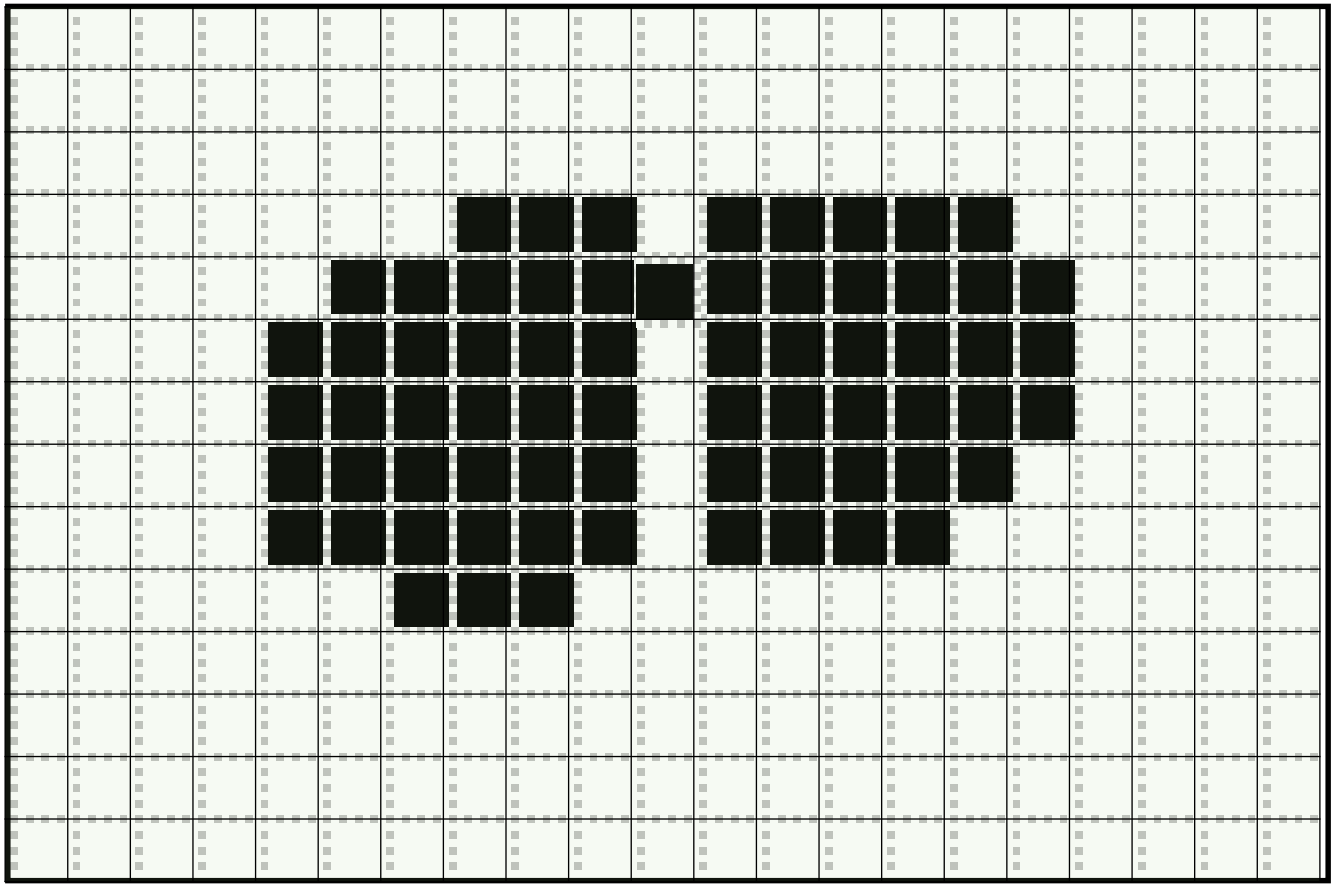
Ming-Han Tsai
Department of Information Engineering and Computer Science,
Feng Chia University

# Grayscale Morphology

# Morphological Operation

Morphological Dilation: take the maximum under the kernel

Morphological Erosion: take the minimum under the kernel



**kernel**

**4-connected**

| | | |
|---|---|---|
| | 1 | |
| 1 | 1 | 1 |
| | 1 | |

☆: anchor

**8-connected**

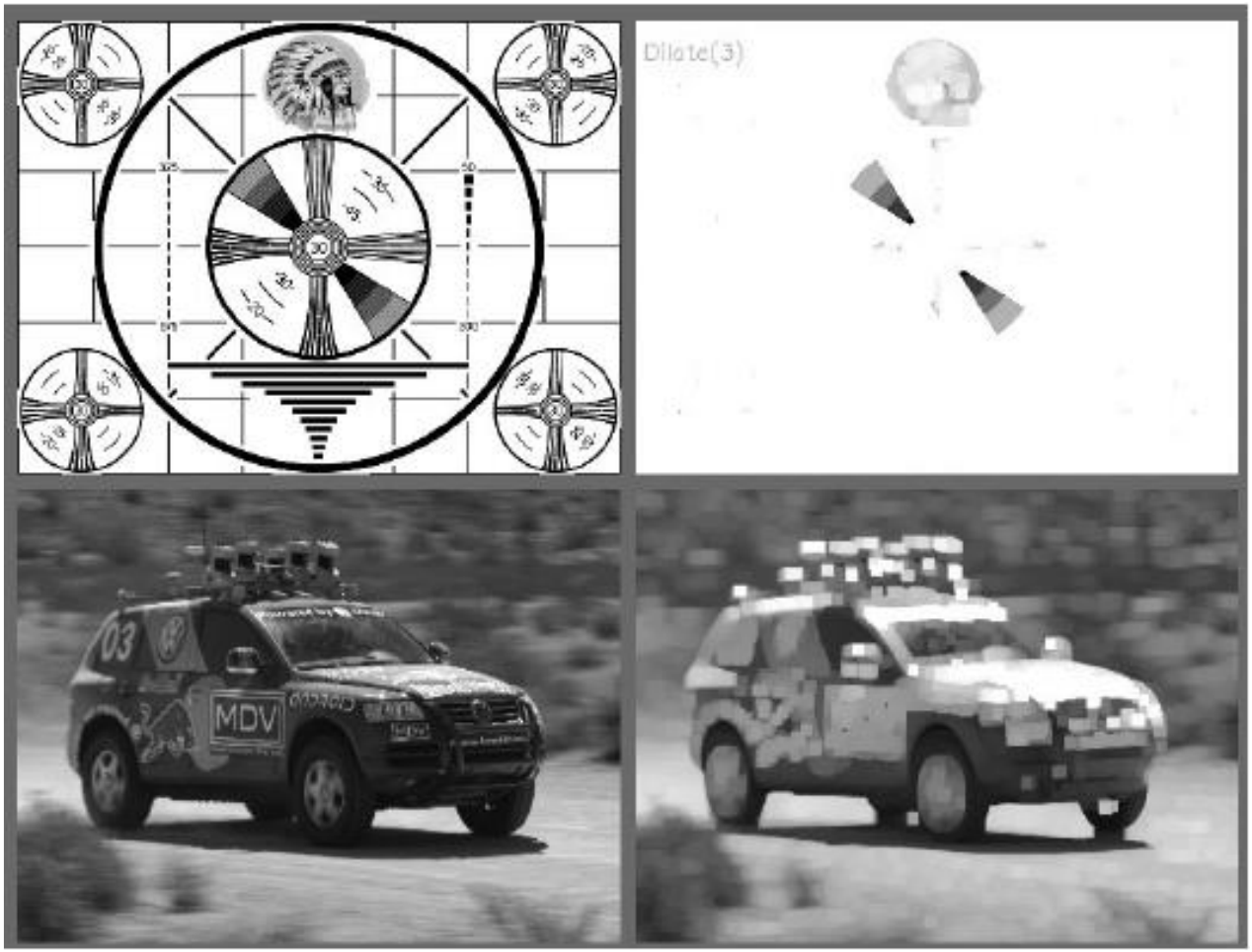
| | | |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 1 | 1 |
| 1 | 1 | 1 |

Kernel, Mask, Structuring element

# Example – grayscale image

$$\text{dilate}(x, y) = \max_{(x', y') \in \text{kernel}} \text{src}(x + x', y + y')$$

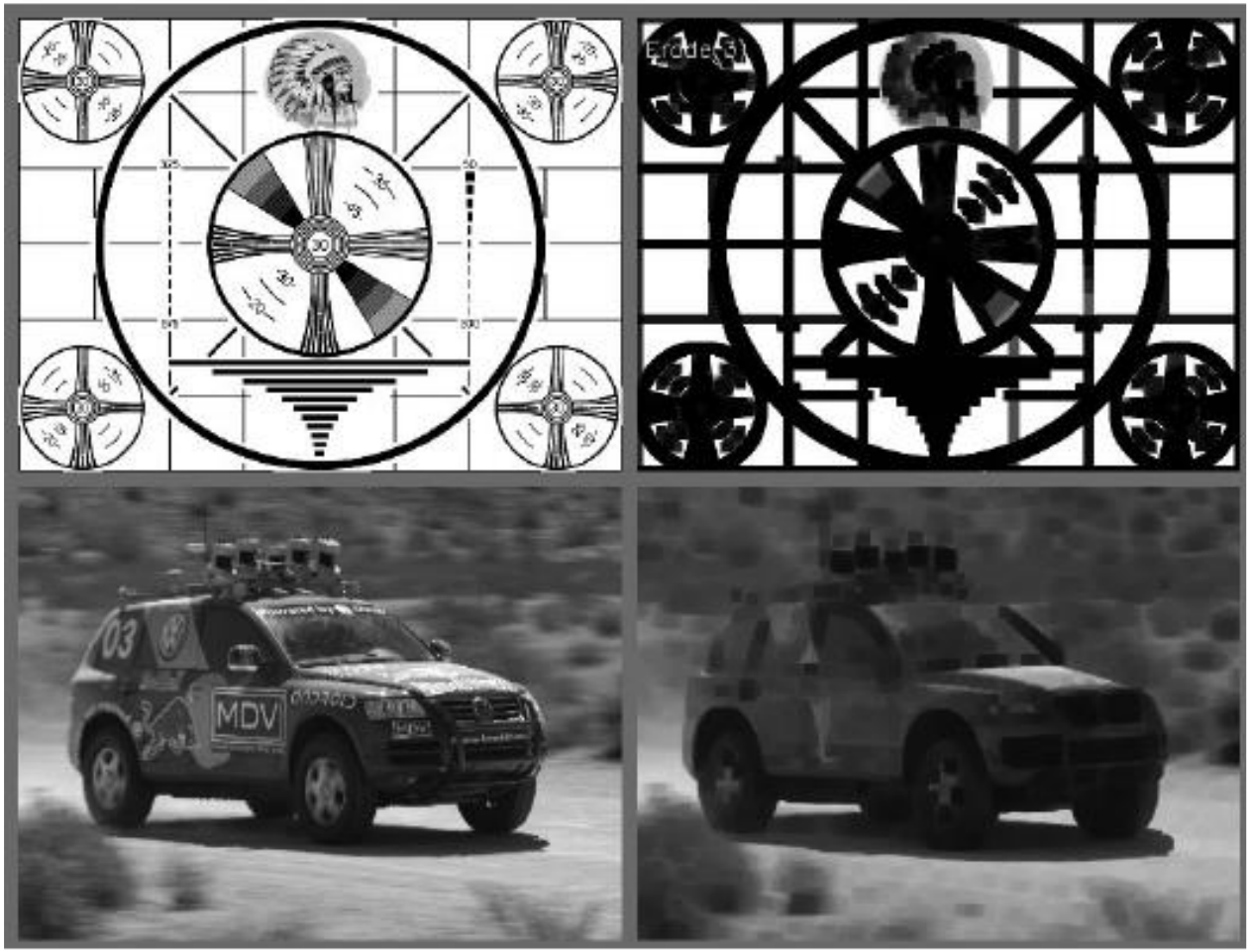
| | | |
|---|---|---|
| 1 | 1 | 1 |
| 1 | ☆ | 1 |
| 1 | 1 | 1 |



# Example – grayscale image

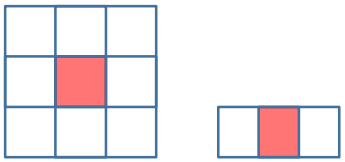
$$\text{erode}(x,y) = \min_{(x',y')\in \text{kernel}} \text{src}(x+x',y+y')$$

| | | |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 1 | 1 |
| 1 | 1 | 1 |



# Morphological Opening

- open(src) = dilate(erode(src)) : erode → dilate
  (Erode: min, Dilate: max)



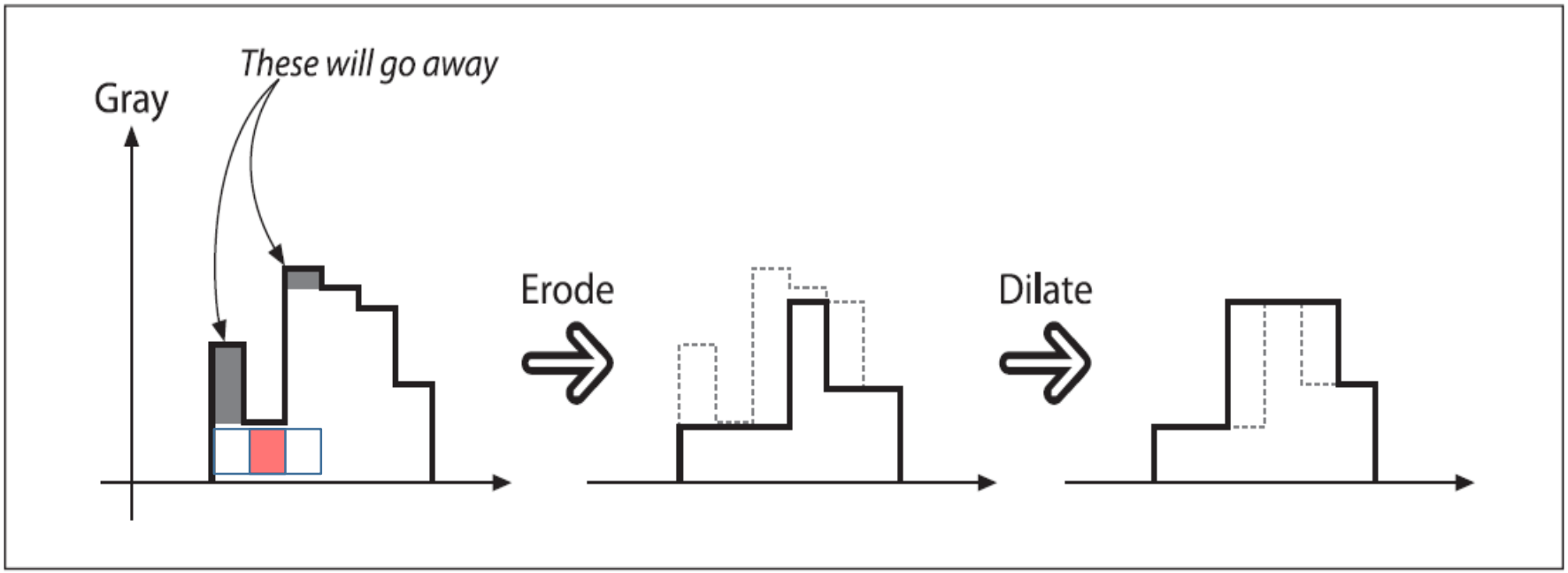
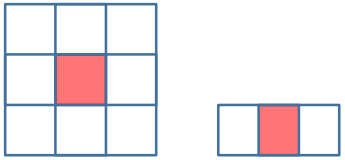



*Figure 5-10. Morphological opening operation: the upward outliers are eliminated as a result*

Open: 斷開

# Morphological Closing

- close(src) = erode(dilate(src)) : dilate → erode
  (Dilate: max, Erode: min)



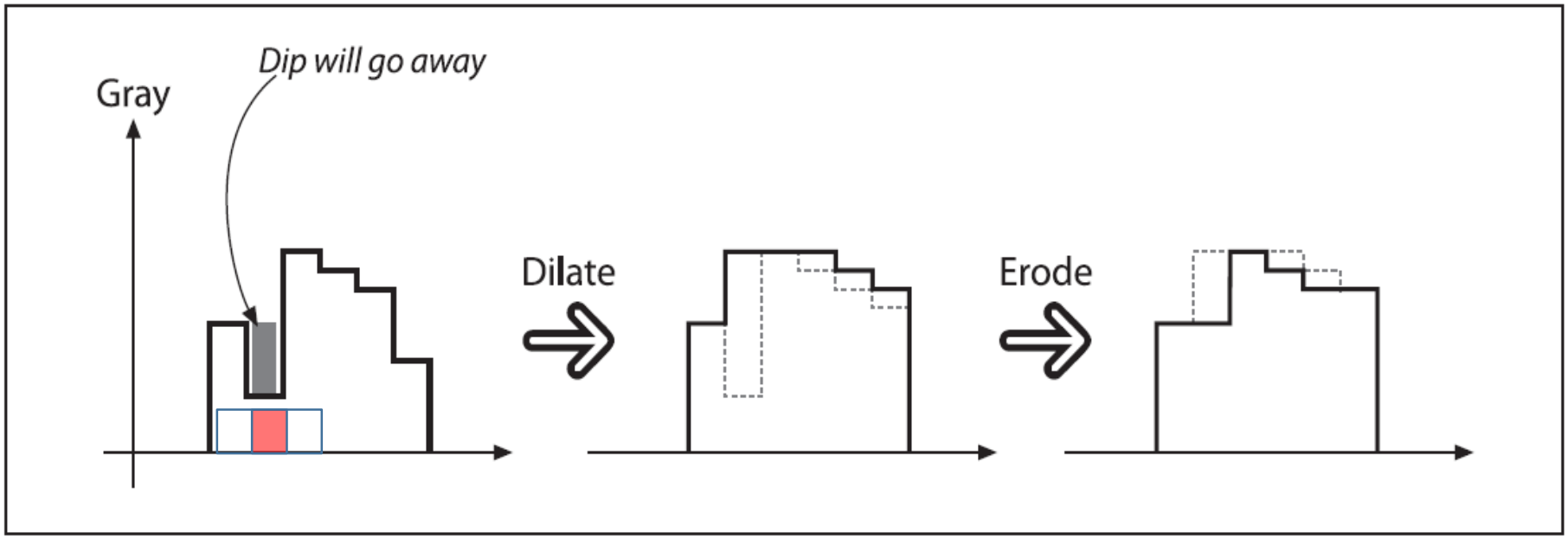


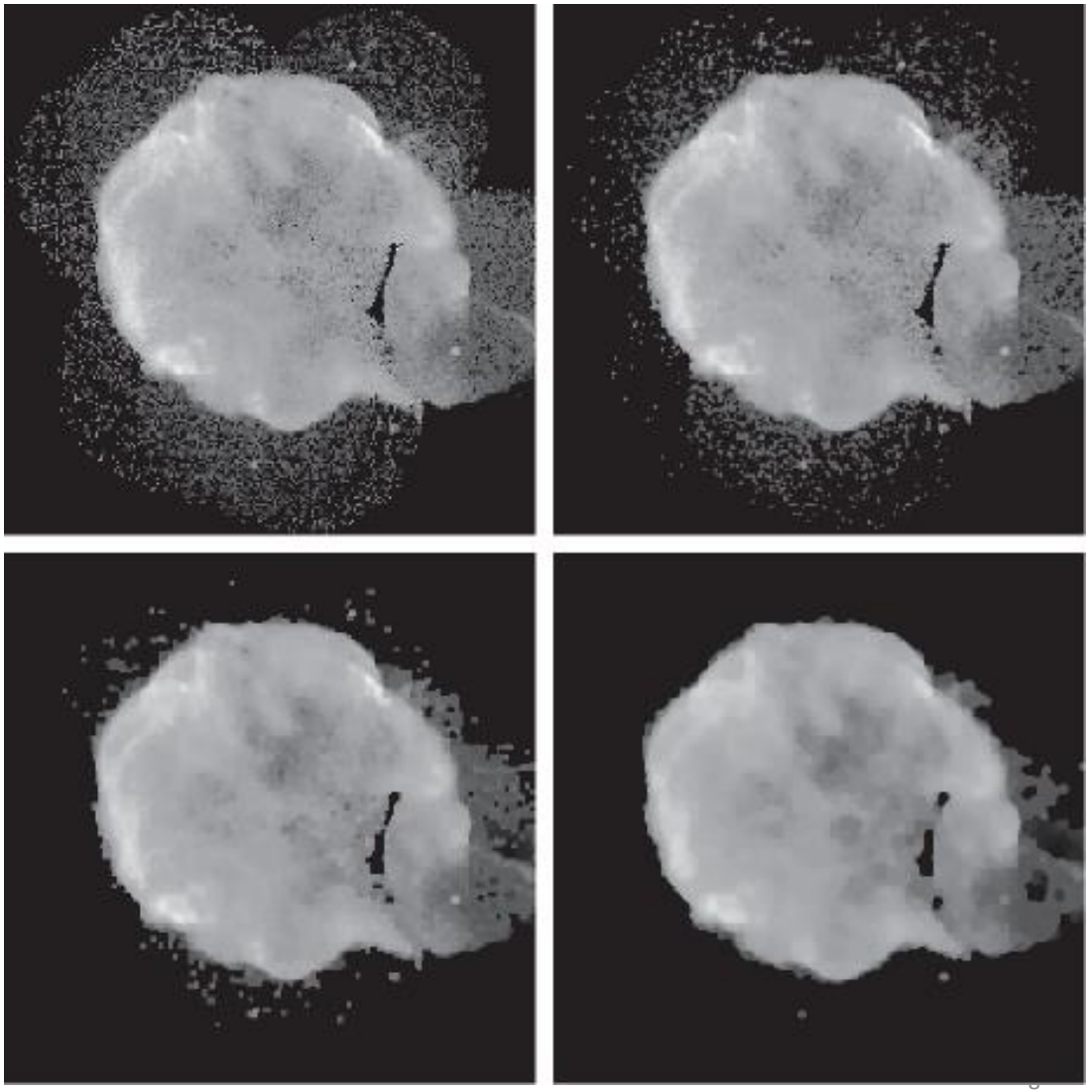

*Figure 5-12. Morphological closing operation: the downward outliers are eliminated as a result*

Close: 閉合

# Morphological Filter

- (a) Source Image
- (b)~(d) Opening + Closing using 1x1,3x3, 5x5 S.E

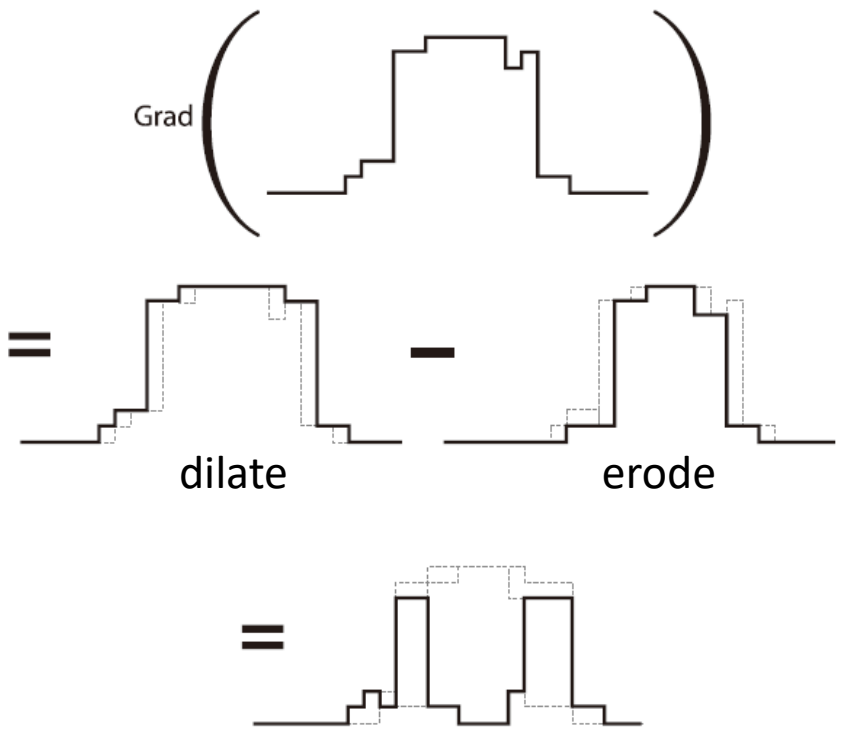
- (a)天鵝座環超新星的566x566影像。(b)~(d)分別以半徑1、3、5的結構原素對原始影像作opening+closing的結果。
- 中央亮區為感興趣的物件，較小的則為雜訊。
- 透過morphological operation，雜訊逐漸被濾除。
- 因雜訊密度的關係，影像下方的雜訊無法完全濾除。



# Morphological Gradient

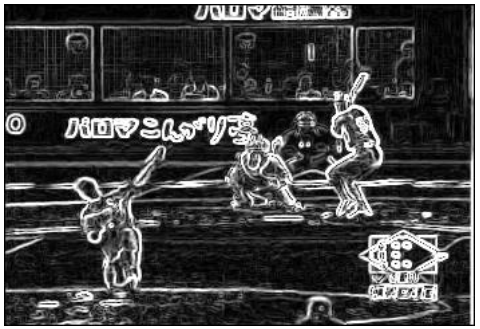
- gradient(src) = dilate(src)-erode(src)
- Dilate: enlarge the area
- Erode: reduce the area

gradient(src) = dilate(src)-erode(src)




The operator has its highest values where grayscale image is changing most rapidly.

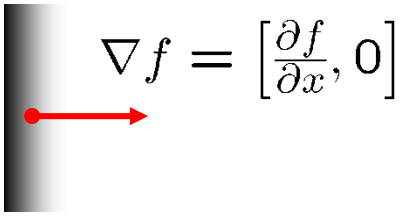
# Image gradient



- The gradient of an image:

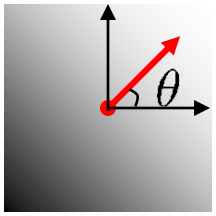
$$\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right]$$

- The gradient points in the direction of most rapid change in intensity



$$\nabla f = \left[\frac{\partial f}{\partial x}, 0\right]$$

$$\nabla f = \left[0, \frac{\partial f}{\partial y}\right]$$




$$\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right]$$

The gradient direction is given by:

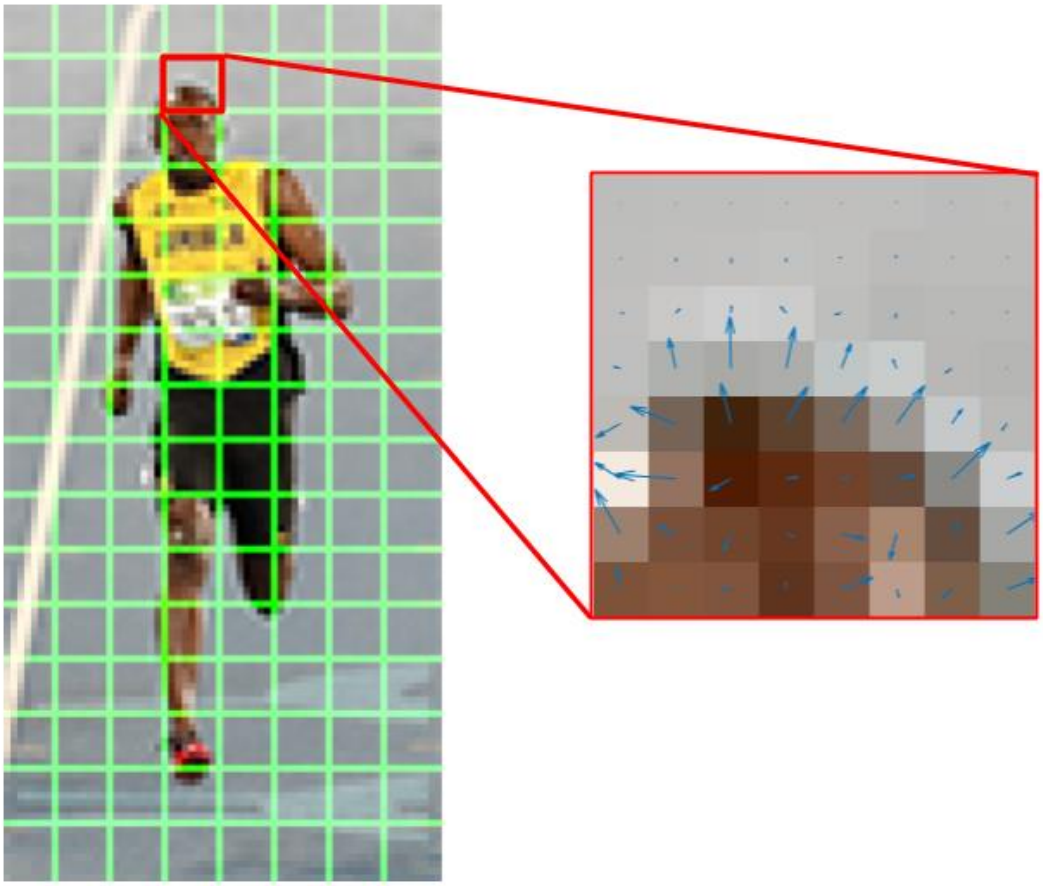
$$\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$$

The edge strength is given by the gradient magnitude

$$\|\nabla f\| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}$$

# Histogram of oriented gradient (HOG)

- The image is divided into 8×8 cells and a histogram of gradients is calculated for each 8×8 cell.



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | 3 | 4 | 4 | 3 | 4 | 2 | 2 |
| 5 | 11 | 17 | 13 | 7 | 9 | 3 | 4 |
| 11 | 21 | 23 | 27 | 22 | 17 | 4 | 6 |
| 23 | 99 | 165 | 135 | 85 | 32 | 26 | 2 |
| 91 | 155 | 133 | 136 | 144 | 152 | 57 | 28 |
| 98 | 196 | 76 | 38 | 26 | 60 | 170 | 51 |
| 165 | 60 | 60 | 27 | 77 | 85 | 43 | 136 |
| 71 | 13 | 34 | 23 | 108 | 27 | 48 | 110 |

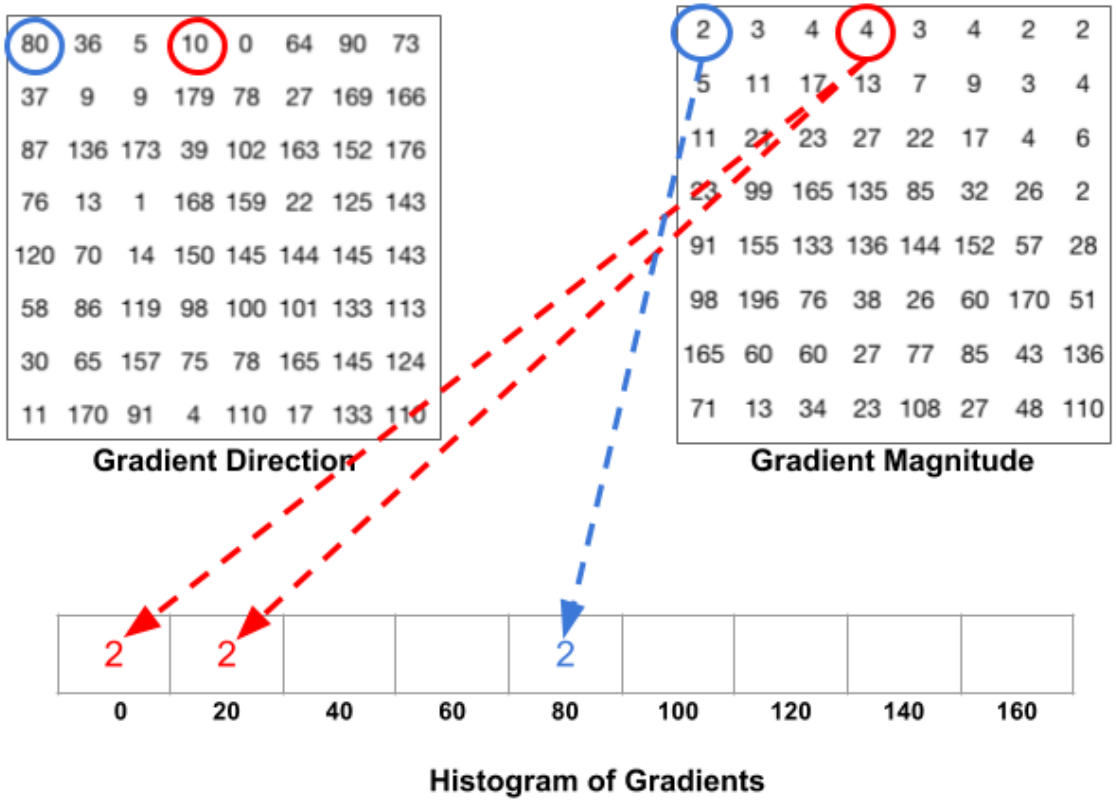
**Gradient Magnitude**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 80 | 36 | 5 | 10 | 0 | 64 | 90 | 73 |
| 37 | 9 | 9 | 179 | 78 | 27 | 169 | 166 |
| 87 | 136 | 173 | 39 | 102 | 163 | 152 | 176 |
| 76 | 13 | 1 | 168 | 159 | 22 | 125 | 143 |
| 120 | 70 | 14 | 150 | 145 | 144 | 145 | 143 |
| 58 | 86 | 119 | 98 | 100 | 101 | 133 | 113 |
| 30 | 65 | 157 | 75 | 78 | 165 | 145 | 124 |
| 11 | 170 | 91 | 4 | 110 | 17 | 133 | 110 |

**Gradient Direction**

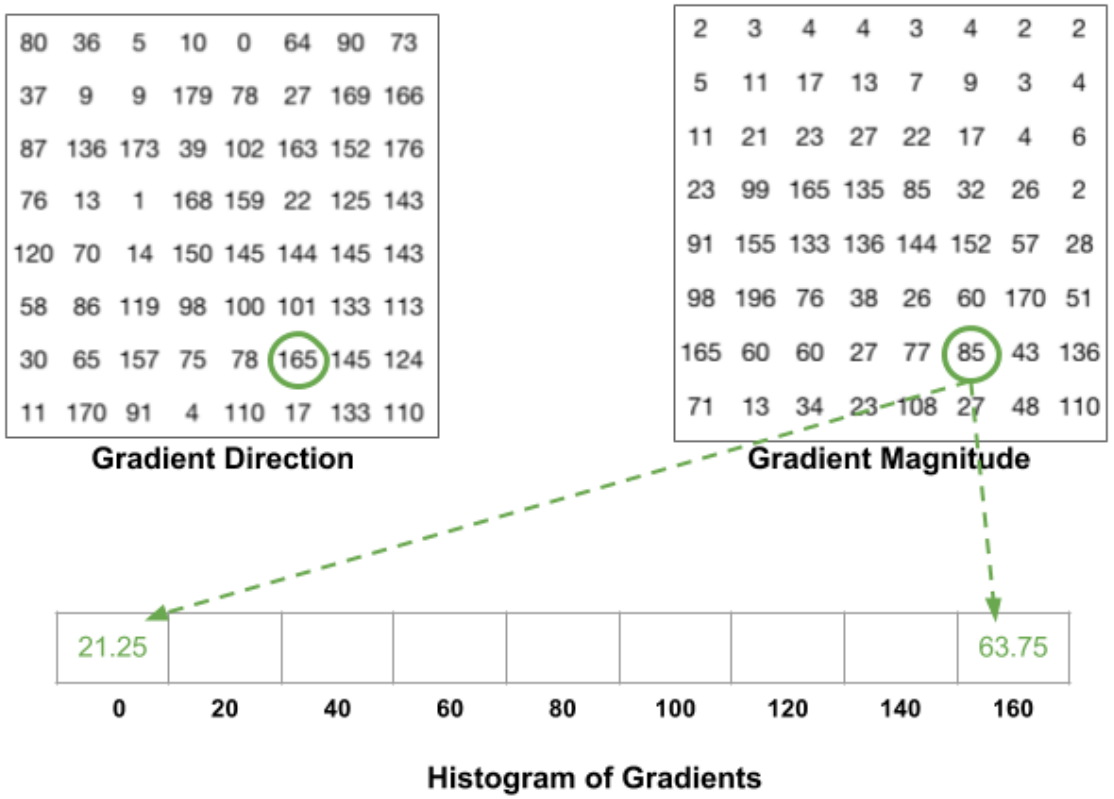
# Histogram of oriented gradient (HOG)

- The histogram is essentially a vector ( or an array ) of 9 bins ( numbers ) corresponding to angles 0, 20, 40, 60 … 160.
- The gradient at the pixel encircled using red has an angle of 10 degrees and magnitude of 4. Since 10 degrees is half way between 0 and 20, the vote by the pixel splits evenly into the two bins.



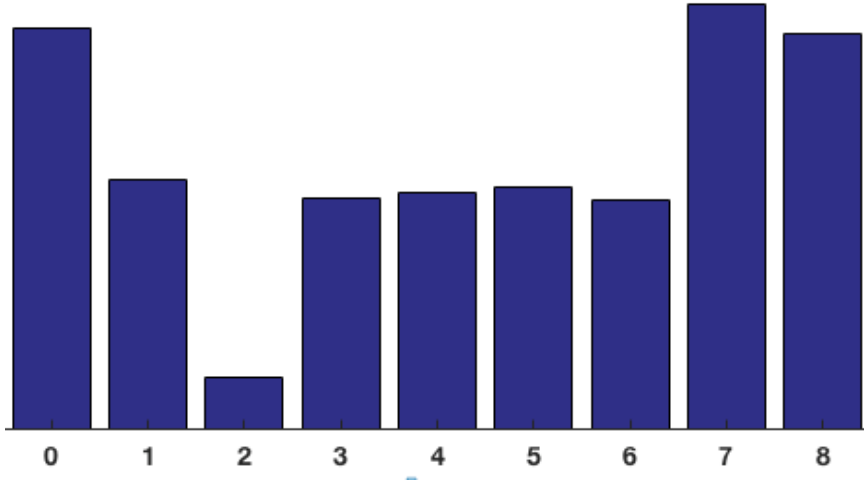
# Histogram of oriented gradient (HOG)

- If the angle is greater than 160 degrees, it is between 160 and 180, and we know the angle wraps around making 0 and 180 equivalent.
- So in the example below, the pixel with angle 165 degrees contributes proportionally to the 0 degree bin and the 160 degree bin.

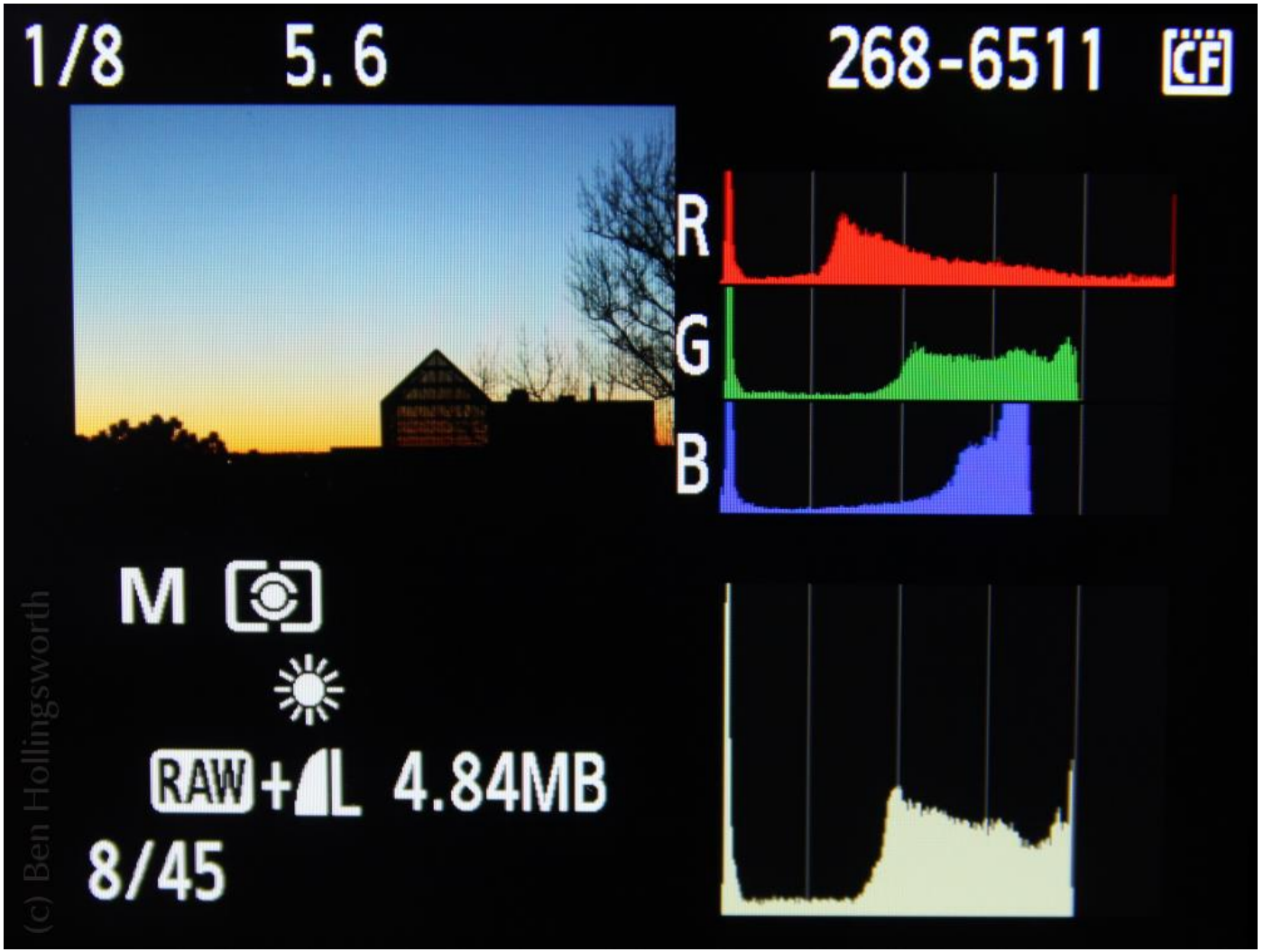


# Histogram of oriented gradient (HOG)

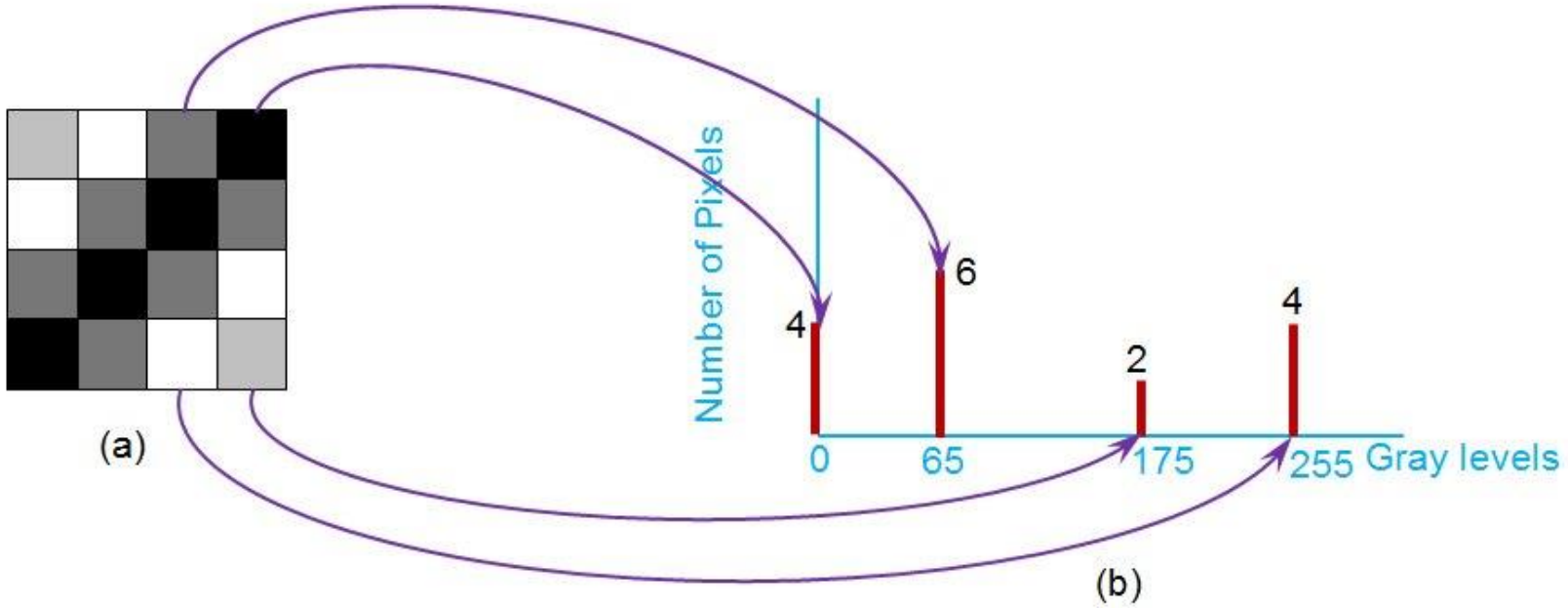
- The contributions of all the pixels in the 8×8 cells are added up to create the 9-bin histogram. For the patch above, it looks like this.
- In our representation, the y-axis is 0 degrees.
- You can see the histogram has a lot of weight near 0 and 180 degrees, which is just another way of saying that in the patch gradients are pointing either up or down.

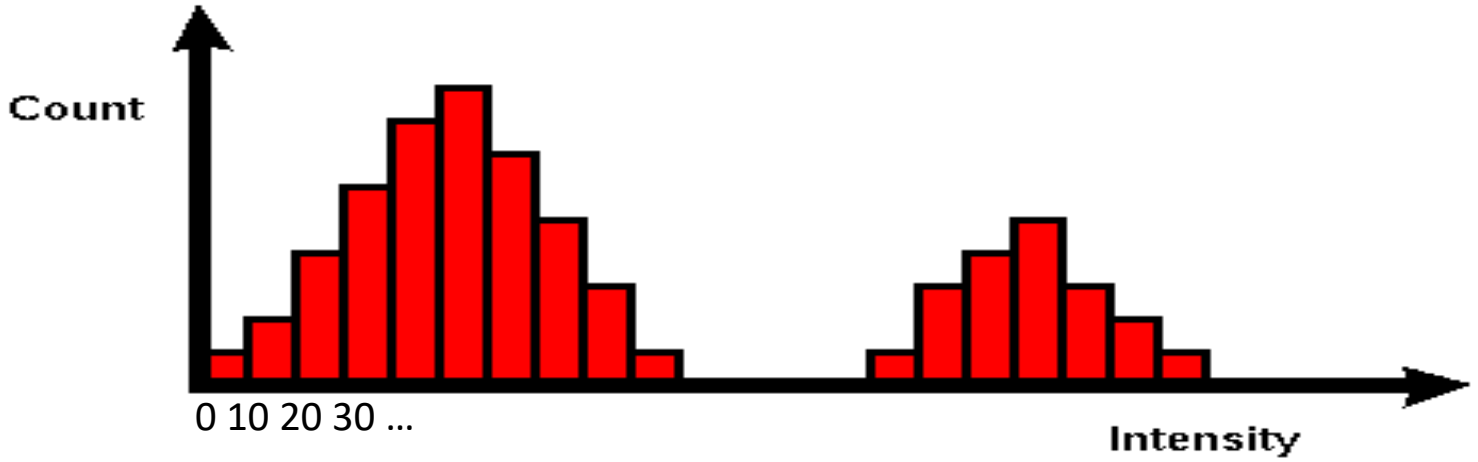


# Color histogram

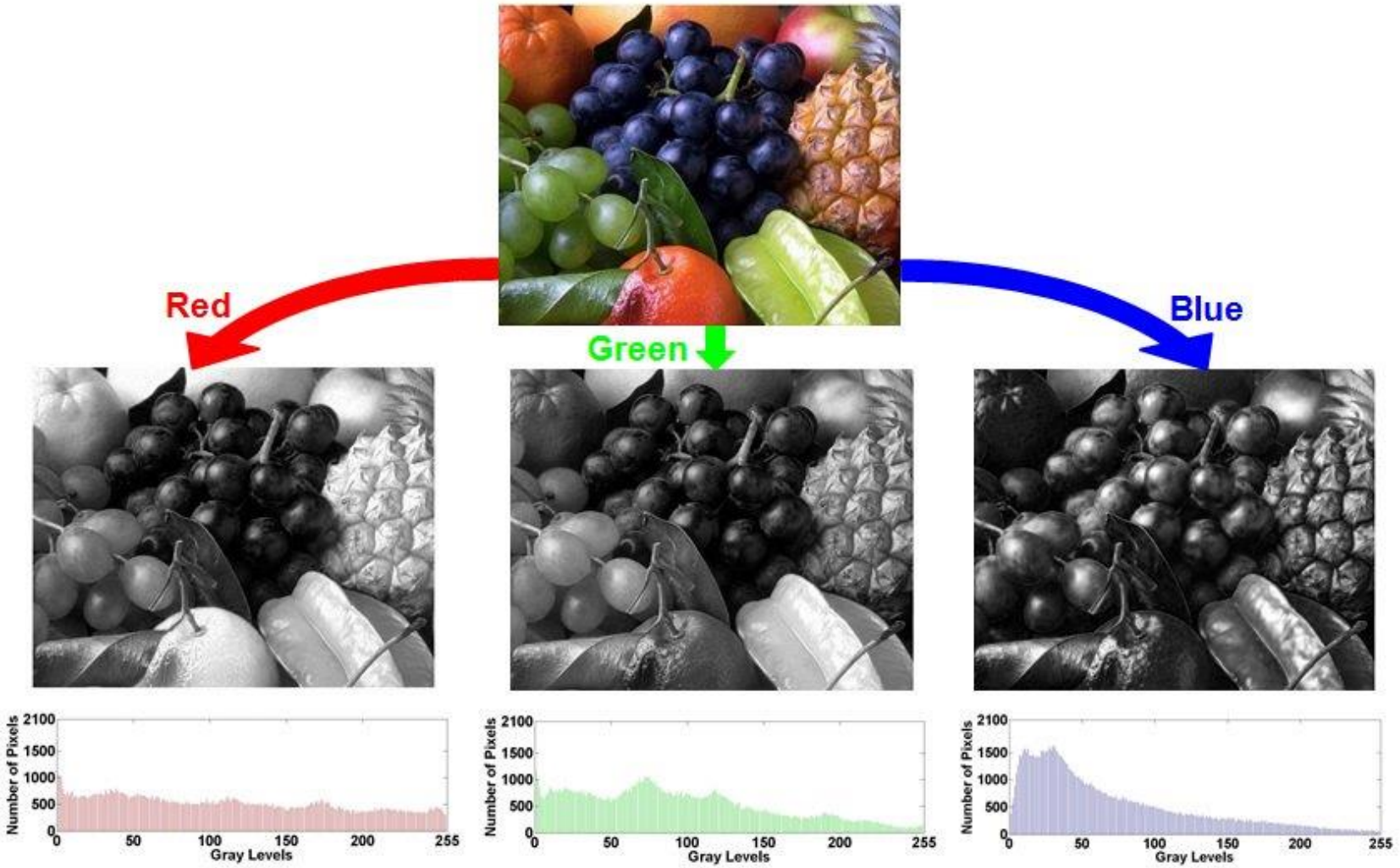


# Color histogram



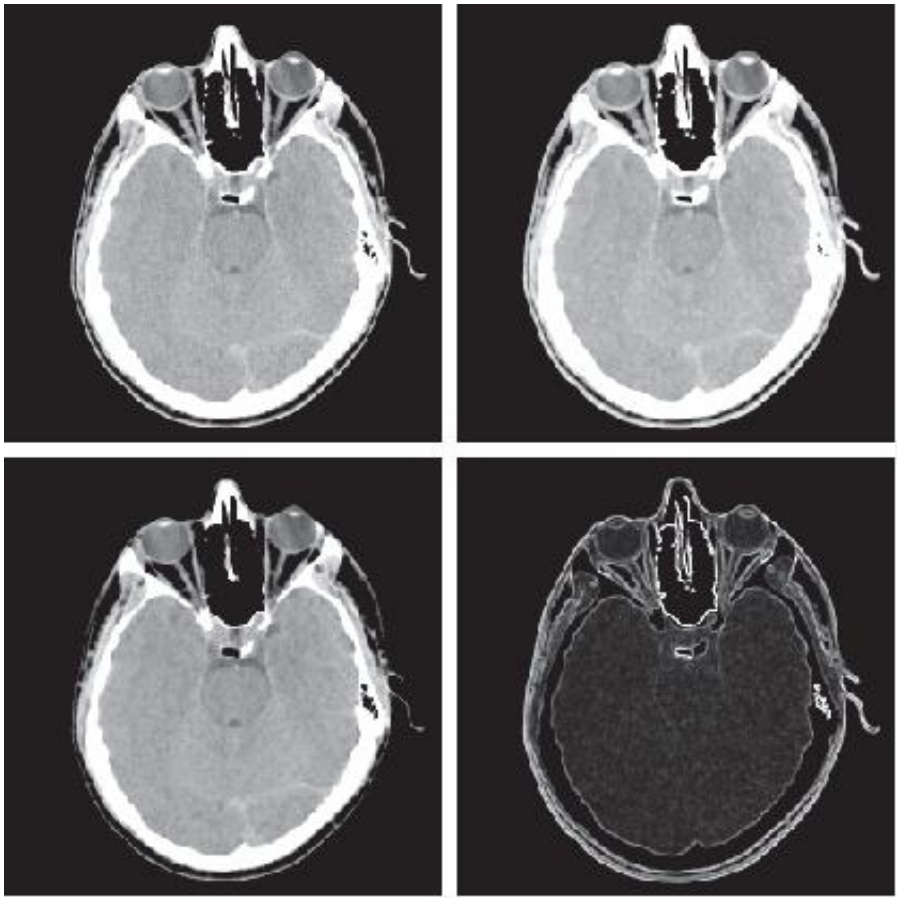
# Color histogram



# Morphological gradient

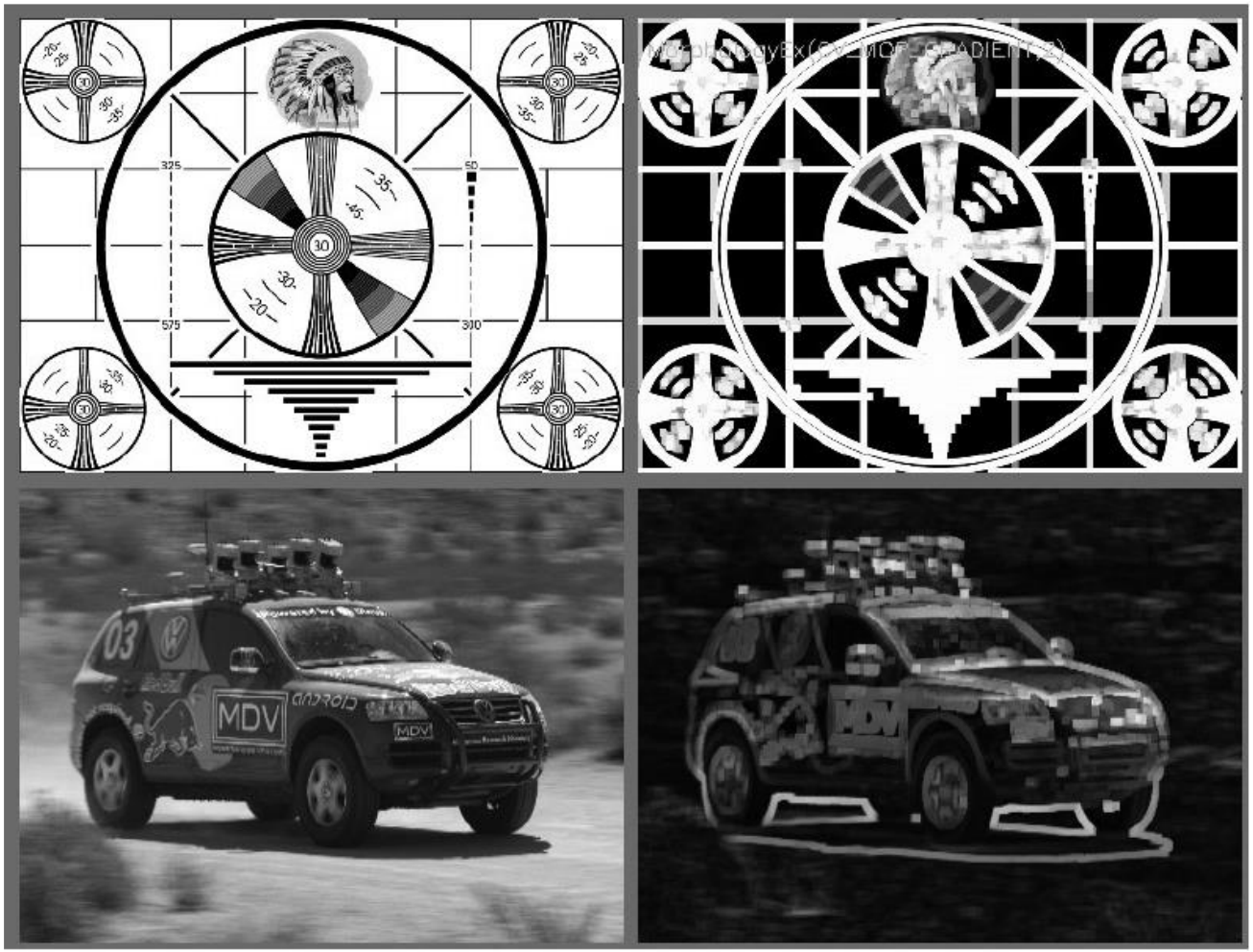
- gradient(src) = dilate(src)-erode(src)

(a) 頭部的CT掃描
(b) 膨脹
(c) 侵蝕
(d) 差異形成梯度



# Morphological gradient

- gradient(src) = dilate(src)-erode(src)

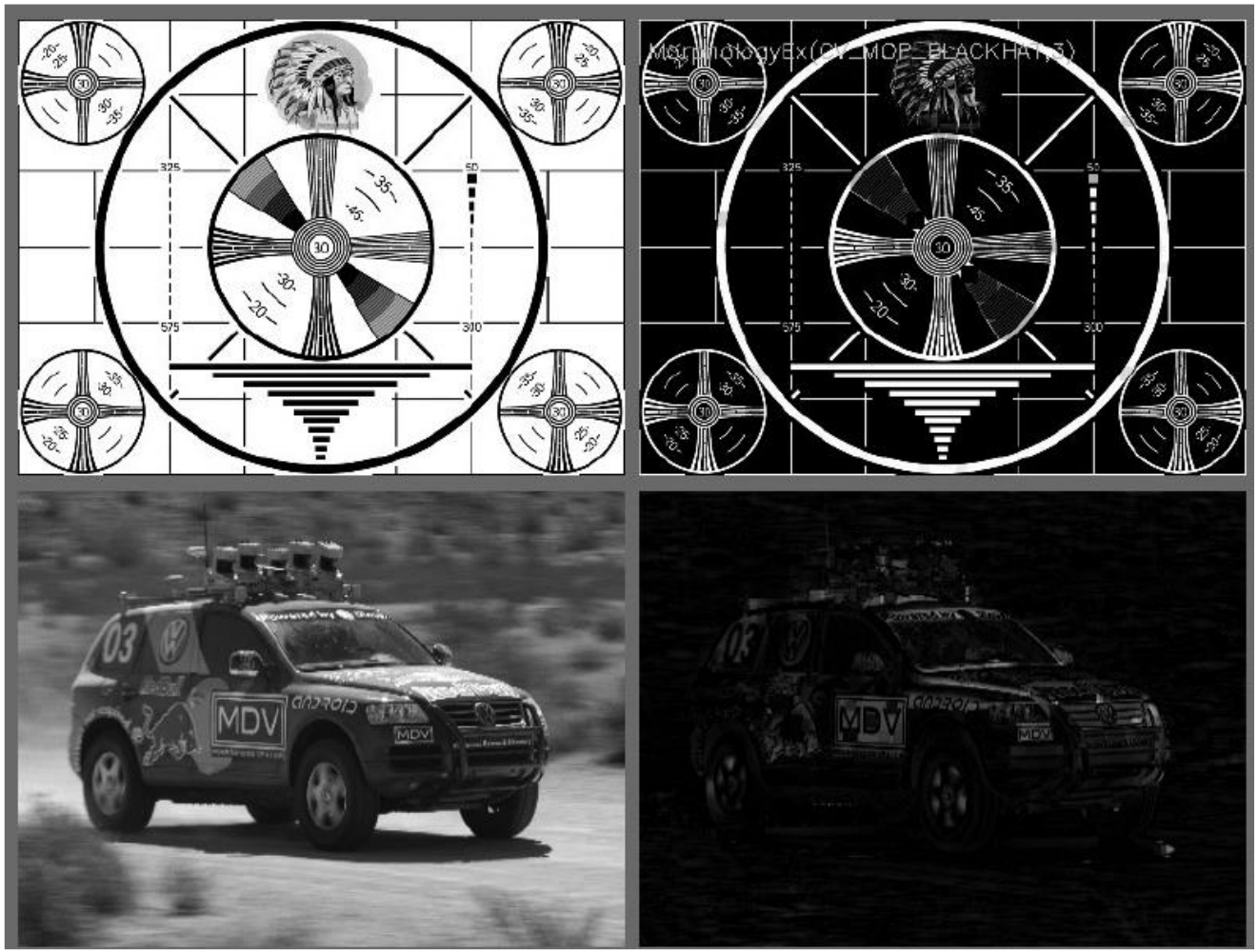


# Morphological Top Hat

- TopHat(src) = src – Open(src) → bright local peaks are isolated

# Morphological Black Hat

- BlackHat(src) = Close(src) – src →dark holes are isolated

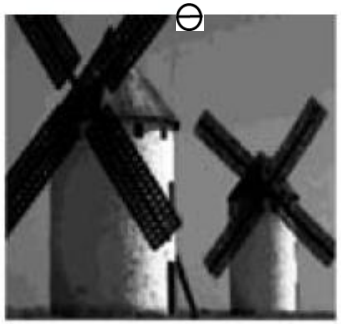


# Morphological Operation --Summary

- morphologyEx (src, dst, **op,** kernel, iterations, borderType, borderValue)
- **MORPH_OPEN** - an opening operation
  **MORPH_CLOSE** - a closing operation
  **MORPH_GRADIENT** - a morphological gradient
  **MORPH_TOPHAT** - "top hat"
  **MORPH_BLACKHAT** - "black hat"

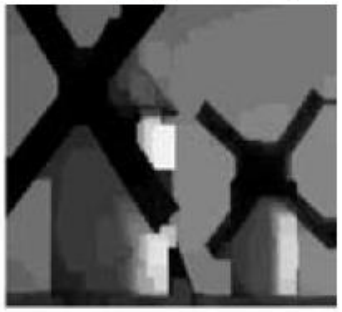
Image I

Erosion $I \ominus B$



Dialation $I \oplus B$

Opening $I \circ B = (I \ominus B) \oplus B$



Closing $I \bullet B = (I \oplus B) \ominus B$

Grad(I)= $(I \oplus B) - (I \ominus B)$

TopHat(I)= $I - (I \ominus B)$

BlackHat(I)= $(I \ominus B) - I$

# Example – Shading correlation

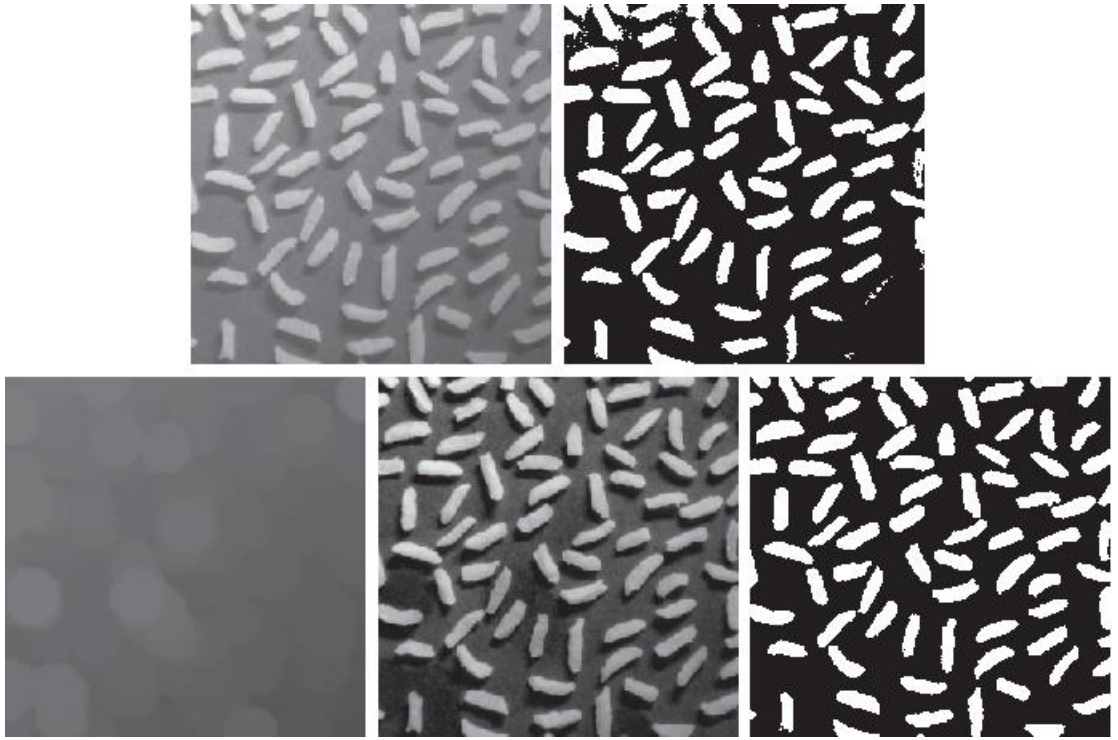
(a) Rice Image: 600×600, darker in the lower-right area。

(b) Thresholding on source image

(c) Opening operation with 40x40 S.E. Extract the background。

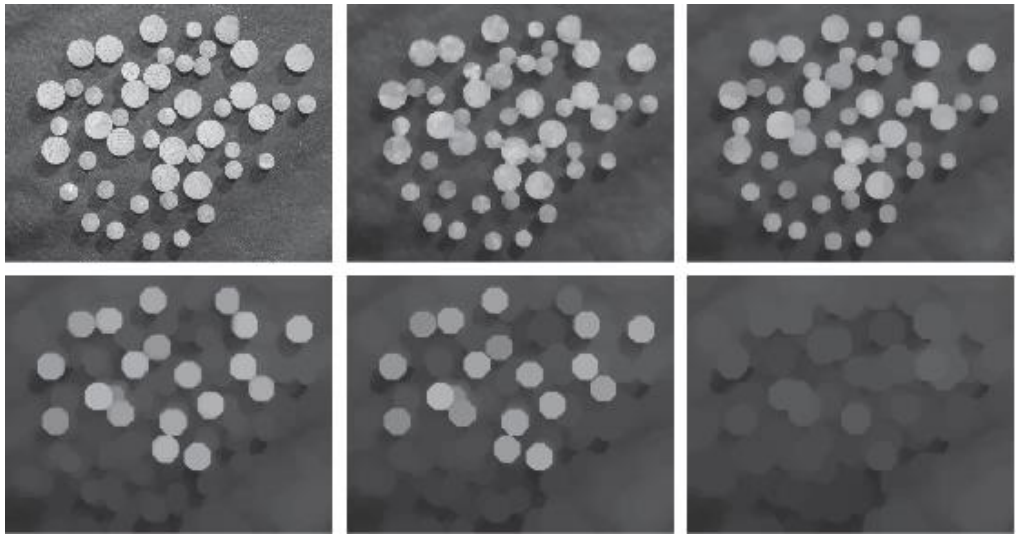
(d) Top-hat Transform: (a) − (c)

(e) Thresholding on (d)



# Example – Granulometry (粗糙度)

- 估算一張影像中粒子顆粒大小
- 假設粒子有規律的形狀且比背景亮，我們可用逐漸增大的SE作斷開(opening)。
- →某一特定大小的opening對大小相近的粒子輸入影像最有效。
- 對每一次作opening後的影像，計算所有像素值的和（稱surface area），此值會隨SE尺寸的增大而減少。

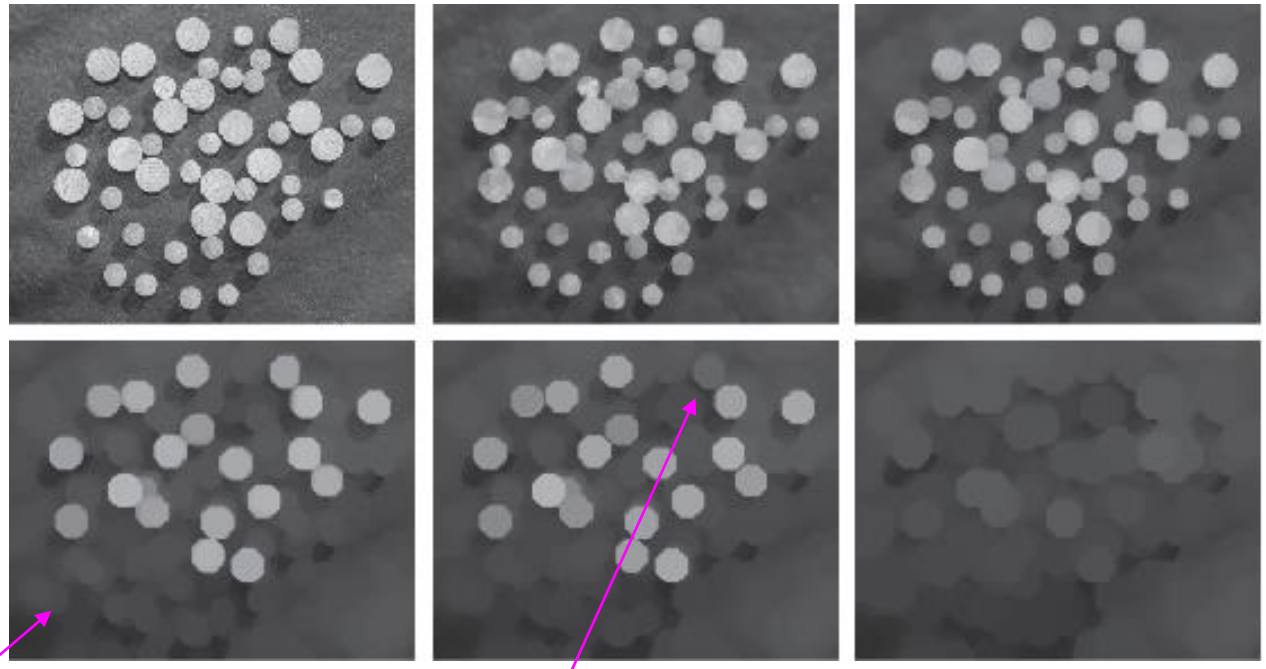


# Example – Granulometry (粗糙度)

(a) Wine corks image (531x675)

(b) Smooth image with circle S.E radius=5

(c) ～(f) opening on (b) with circle S.E radius = 10,20,25,30

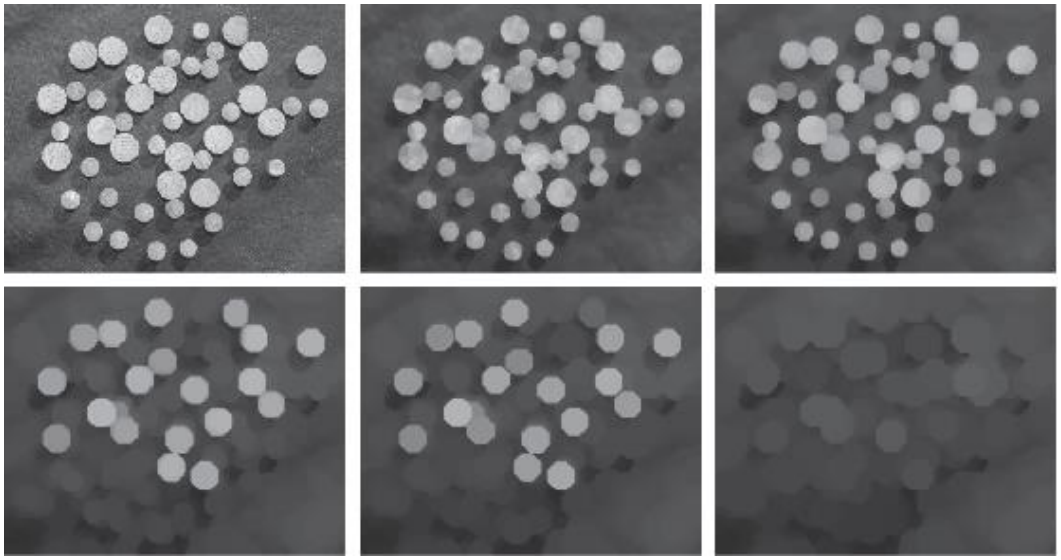


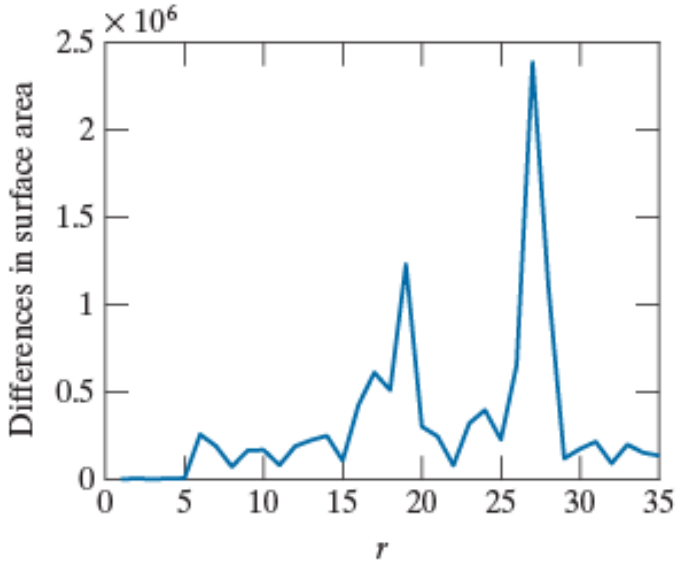
小塞子的強度貢獻大都已被消除

已變暗，因其較小。
→偵測瑕疵品

# Example – Granulometry (粗糙度)

- Calculate the difference of the surface area before/after
- The two peaks in right image means that there are two types of wine corks in the image.





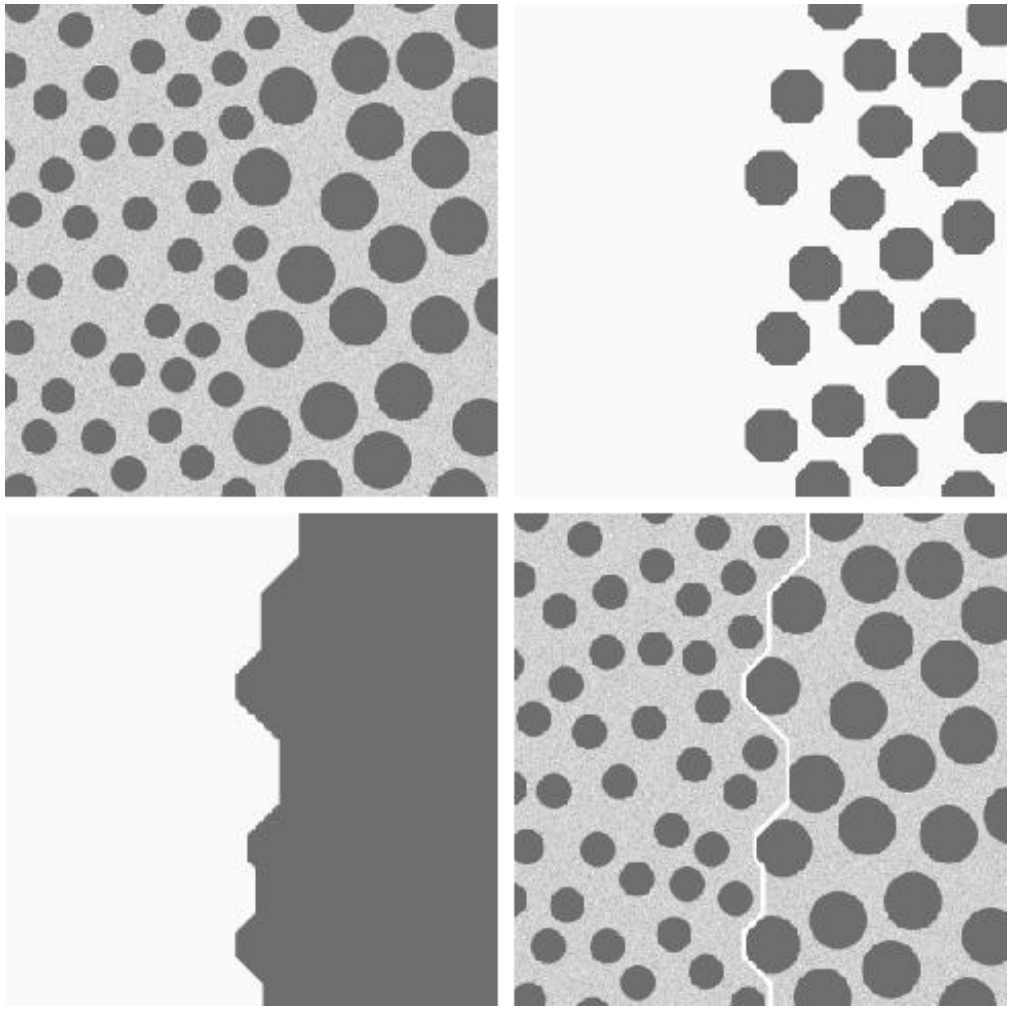
# Example – Textural Segmentation

(a) 兩種暗斑點，在帶有雜訊的亮背景上。

(b) 先以大於小斑點的SE作closing，小斑點會被移除。（SE:l30, 小斑:25）

(c) 再對(b)以大於斑點間距的SE作opening，則斑點間亮的間隙將被移除。（SE: 60）

(d) 以3x3的SE對(c)作梯度計算，則可產生兩區域間的邊界。



- Q&A