# Image & Color





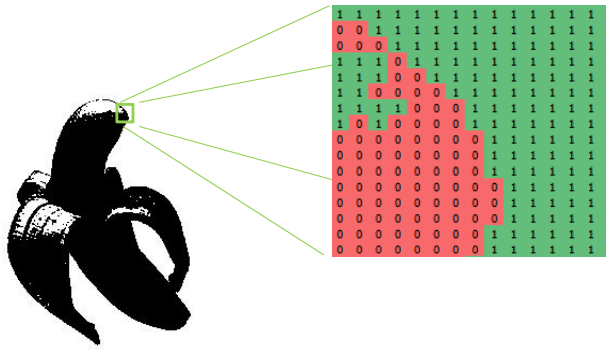
**Binary Image**

**Grayscale Image**

**Color Image**



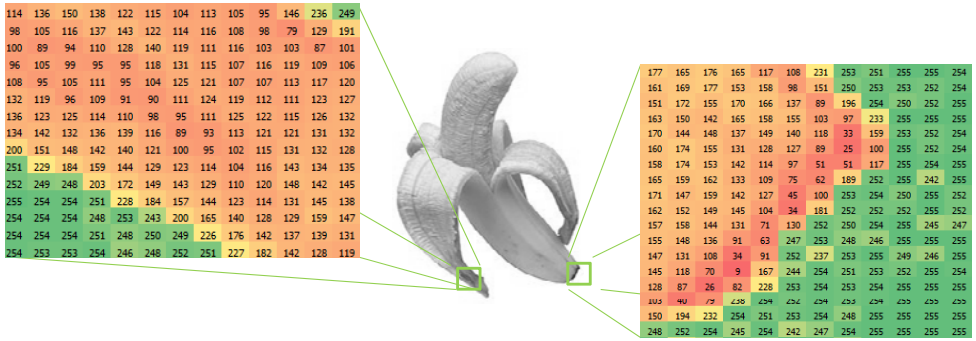




**Binary Image**

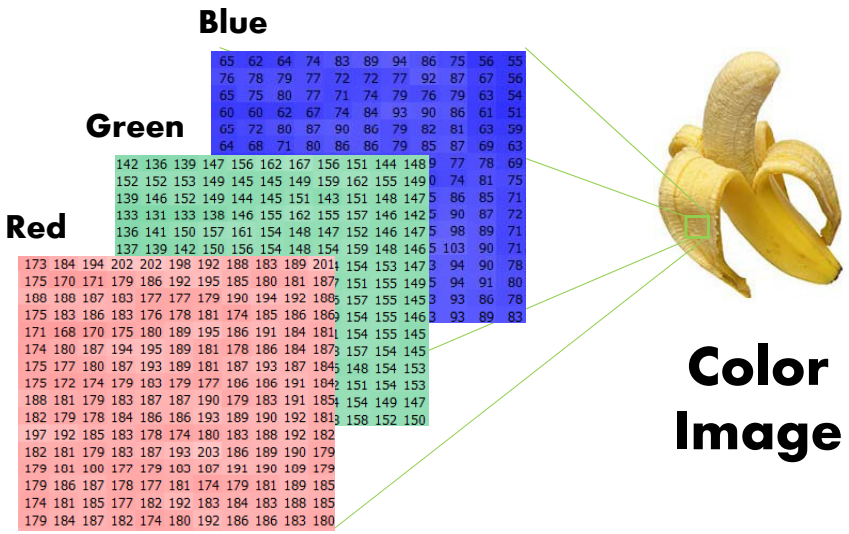






**Grayscale Image**

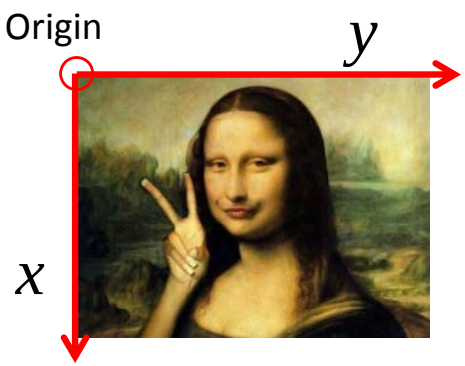
8-bit => 0-255








# Image = 2-D Function




$$I(x, y)$$

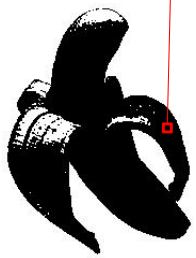
Pixel Coordinates





Scalar

$$I(x, y) \in \{0,1\}$$

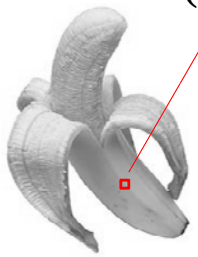


**Binary Image**

Scalar

$$I(x, y) \in \{0,1,2,....,255\}$$

(for 8-bit image)



**Grayscale Image**



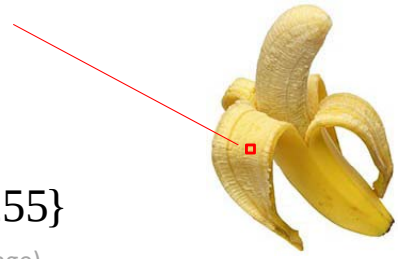


Vector

$$I(x, y) = \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

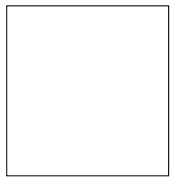
$$r, g, b \in \{0,1,2,....,255\}$$

(for 8-bit image)



**Color Image**

r,g,b = Color components
(Red, Green, Blue Components)

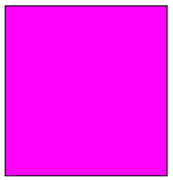


Ⓐ [255 255 255]

Ⓑ [0 0 0]







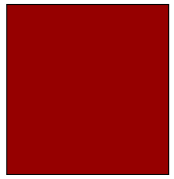
Ⓐ [0 255 255]

Ⓑ [255 0 255]

Ⓒ [255 255 0]







Ⓐ [150 0 0]

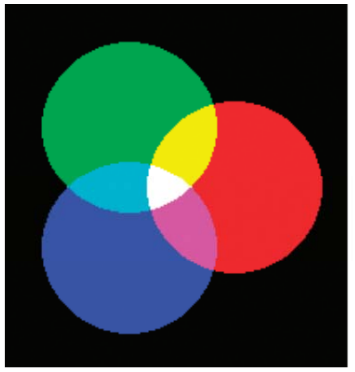
Ⓑ [255 0 0]

Ⓒ [255 150 150]





# RGB Color Space



$$I(x,y) = \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

Red light

Green light

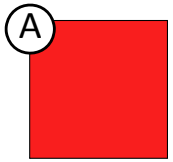
Blue light

**Mixture of Lights**

[128 0 0]

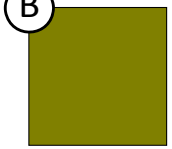
**Which one is more similar?**

A



[250 30 30]

B

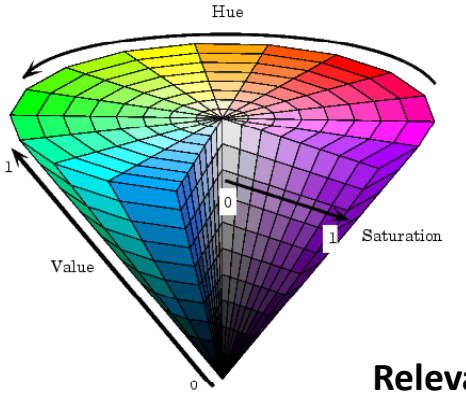


[128 128 0]





# HSV Color Space




$$I(x,y) = \begin{bmatrix} h \\ s \\ v \end{bmatrix}$$

Hue

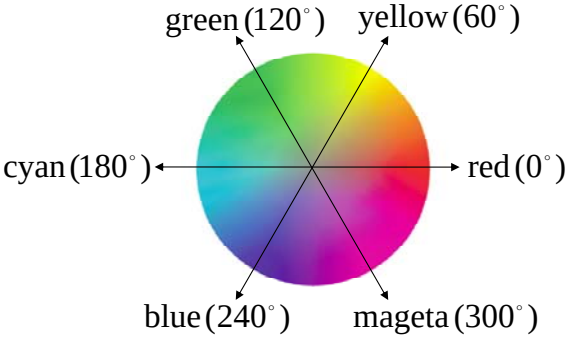
Saturation

Value

**Relevant to human perceptual**








# Hue





# RGB ⇒ HSV

$$M = \max(r,g,b)$$

$$m = \min(r,g,b)$$

$$h = \begin{cases} 0; & M = m \\ \frac{g-b}{M-m} \times 60^\circ \bmod 360^\circ; & M = r \\ \frac{b-r}{M-m} \times 60^\circ + 120^\circ; & M = g \\ \frac{r-g}{M-m} \times 60^\circ + 240^\circ; & M = b \end{cases}$$

$$v = M$$

$$s = 1 - \frac{m}{M}$$

$r, g, b \in [0,255]$

$h \in [0^\circ, 360^\circ]$

$s \in [0,1]$

$v \in [0,255]$

# RGB ⇒ HSV

$$[r\ g\ b] = [128\ \ 0\ \ 0]$$

$$M = \max(r,g,b) = 128$$

$$m = \min(r,g,b) = 0$$

$$h = \frac{g-b}{M-m} \times 60^\circ = 0$$

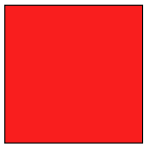
$$v = M = 128$$

$$s = 1 - \frac{m}{M} = 1$$





# RGB ⇒ HSV



$$[r\ g\ b] = [250\ \ 30\ \ 30]$$

$$M = \max(r,g,b) = 250$$

$$m = \min(r,g,b) = 30$$

$$h = \frac{g-b}{M-m} \times 60^\circ = 0$$

$$v = M = 250$$

$$s = 1 - \frac{m}{M} = 0.88$$





# RGB ⇒ HSV

$$[r\ g\ b] = [128\ \ 128\ \ 0]$$

$$M = \max(r,g,b) = 128$$

$$m = \min(r,g,b) = 0$$

$$h = \frac{g-b}{M-m} \times 60^\circ = 60^\circ$$

$$v = M = 128$$

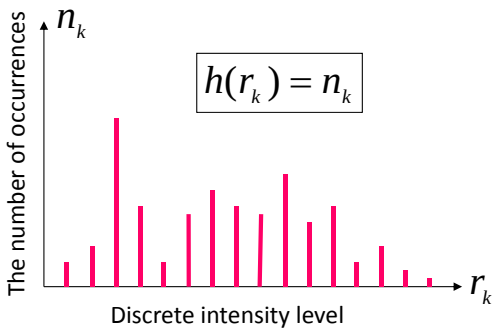
$$s = 1 - \frac{m}{M} = 1$$

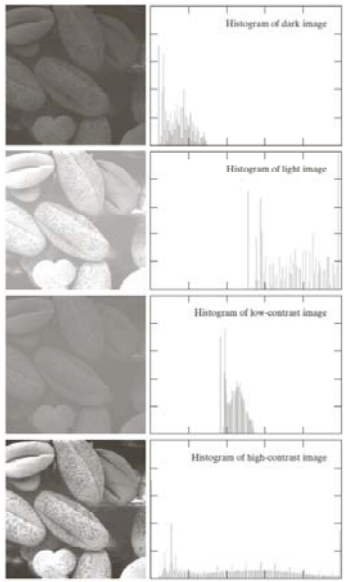




# Histogram

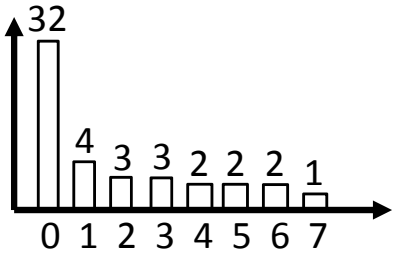
- Representation of the number of occurrences ($n_k$) of each possible intensity level ($r_k$) in the entire image



# Histogram

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 0 | 1 | 0 | 0 | 0 | 3 | 4 |
| 4 | 3 | 0 | 0 | 0 | 3 | 6 |
| 5 | 5 | 0 | 0 | 0 | 2 | 0 |
| 0 | 6 | 7 | 0 | 0 | 0 | 0 |



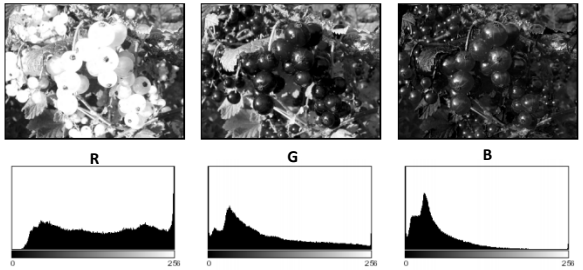





# Histogram for Color Image


Intensity Histograms

$$i = \frac{1}{3}(r + g + b)$$

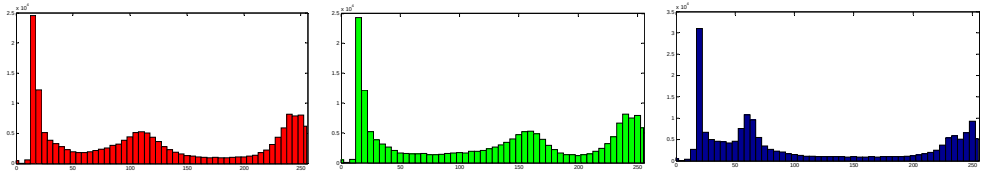


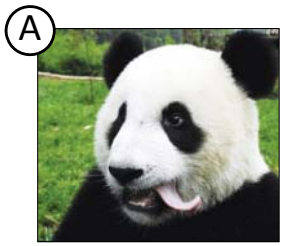

Individual Color Channel Histograms

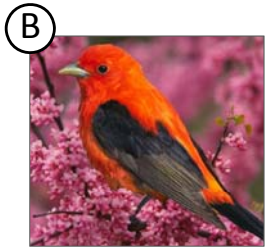




# Histogram for Color Image



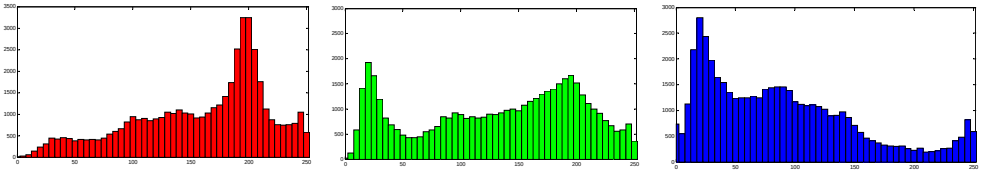


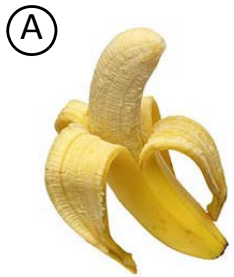



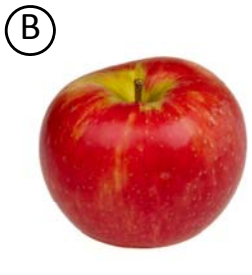


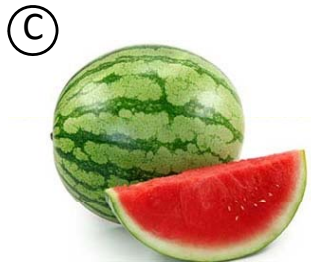



# Histogram for Color Image

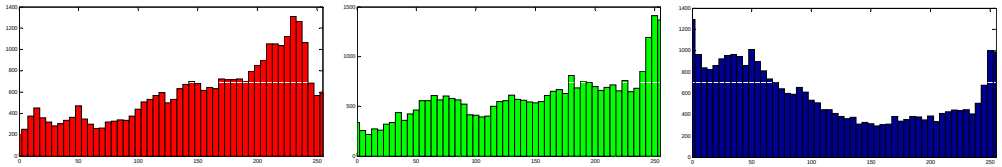




# Histogram for Color Image



Ⓐ 


Ⓑ 


Ⓒ 



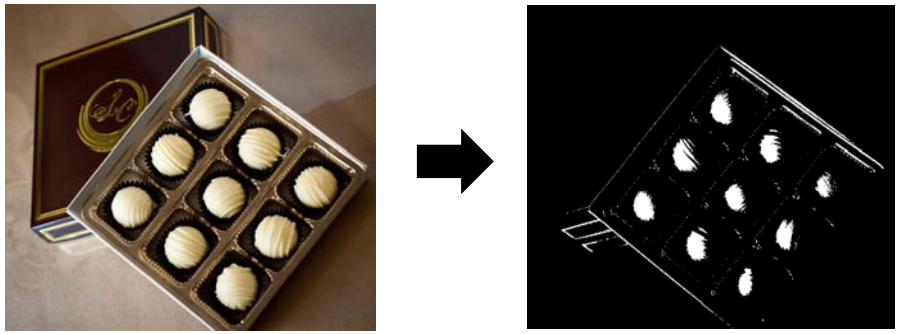



# White Chocolate Counting





# Color Thresholding

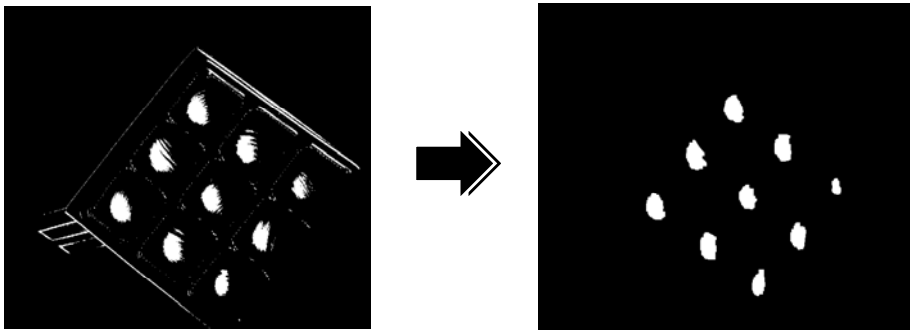


$$r > 230, g > 200, b > 150$$





# Morphological Operators



# Connected Component Labeling

[Blob Detection]

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 |

→

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 2 | 2 | 0 | 0 | 1 | 0 |
| 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| 0 | 3 | 3 | 3 | 0 | 0 | 0 |
| 0 | 0 | 3 | 0 | 0 | 0 | 0 |

**4-Connectivity**





# Connected Component Labeling

[Blob Detection]

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 |

→

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 2 | 2 | 0 | 0 | 1 | 0 |
| 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 0 | 2 | 2 | 2 | 0 | 0 | 0 |
| 0 | 0 | 2 | 0 | 0 | 0 | 0 |

**8-Connectivity**





# Connected Component Labeling

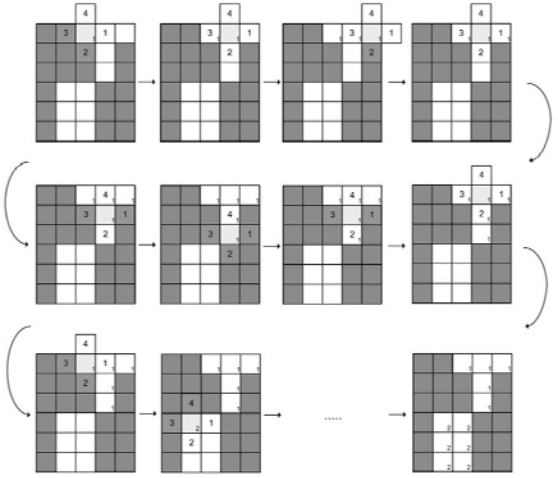
[Blob Detection]





# Connected Component Labeling

[Blob Detection]



http://what-when-how.com/introduction-to-video-and-image-processing/blob-analysis-introduction-to-video-and-image-processing-part-1/

## Two-pass algorithm

- Scan pixel by column, then by row
- If the pixel ≠ background, find the neighbor with the smallest label, assign it to the pixel and Store the equivalence between neighboring labels
- If there are no labeled neighbors, assign the pixel with new label
- Scan image again aand relabel the element with the lowest equivalent label

# Connected Component Labeling

[Blob Detection]

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 2 | 2 | 0 | 3 | 3 | 0 |
| 0 | 2 | 2 | 0 | 3 | 3 | 0 |

Equivalent List





# Connected Component Labeling

[Blob Detection]

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 2 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 3 | 3 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 4 | 4 | 4 | 1 | 1 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |

Equivalent List
1-2, 1-4

1st pass
(8 connectivity )





# Connected Component Labeling

[Blob Detection]

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 2 | 2 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 |

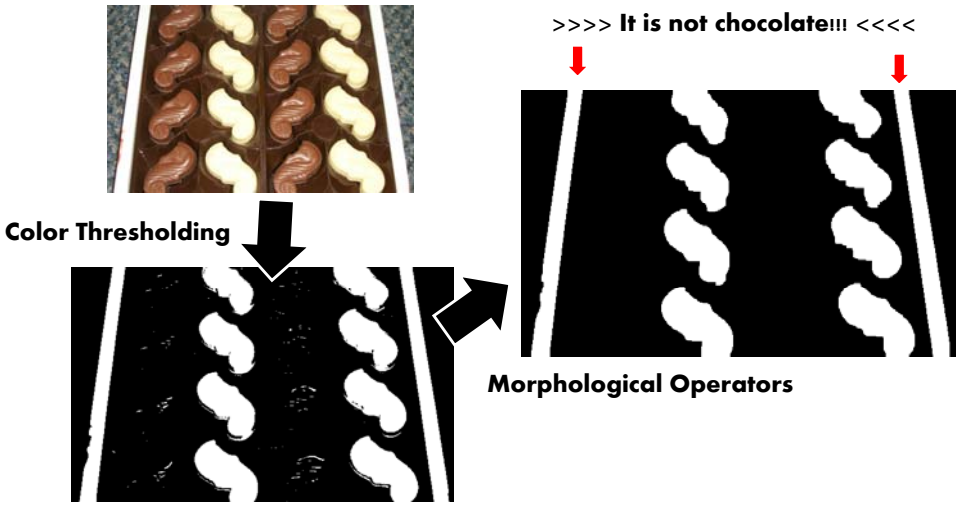
Equivalent List
1-2, 1-4

2nd pass
(8 connectivity )

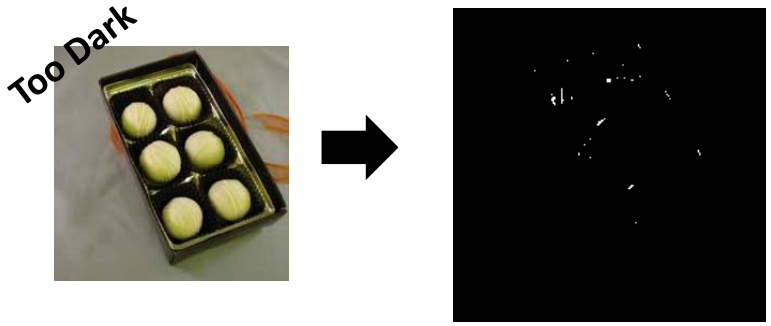




# White Chocolate Counting



# White Chocolate Counting




$$r > 230, g > 200, b > 150$$





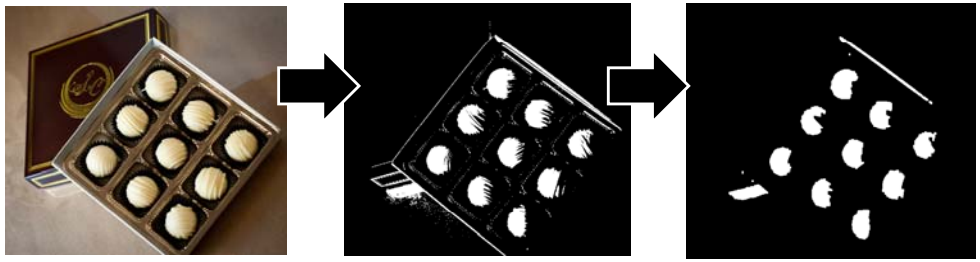
# Change Threshold [= =!]

$$r > 200, g > 170, b > 120$$





# Change Threshold [= =!]



$$r > 200, g > 170, b > 120$$





# Skin Detection

**Try Color Thresholding in HSV space**