A Computational Approach to Edge Detection

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   (1) 去雜訊及 Derivative
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1. 邊緣偵測的準則

1. Good detection
   - 能偵測到所有邊緣，且過濾掉非邊緣點。 -> max(singal/noise)
2. Good localization
   - 計算出來的邊緣的位子與實際邊緣的位子誤差應該盡可能小。
3. Only one response to a single edge
   - 對一個實際邊緣，不應檢測出多個邊緣；應只檢測出一個邊緣。

2. Canny 邊緣偵測的步驟

1. 去除雜訊
2. 計算Derivative
3. 計算梯度的幅度和方向
4. Non-maximum suppression
5. Hysteresis Threashold

(1) 去雜訊及 Derivative

去除雜訊：使用高斯濾波器對影像模糊

$$S = g(x, y) * I$$

$$g(x, y) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Derivative

$$\nabla S = \nabla(g * I) = (\nabla g) * I$$

$$\nabla S = \begin{bmatrix} g_x \\ g_y \end{bmatrix} * I = \begin{bmatrix} g_x * I \\ g_y * I \end{bmatrix}$$

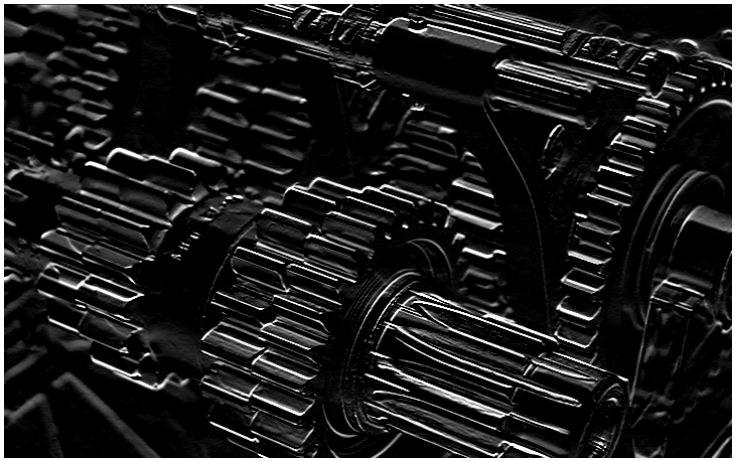
$$\nabla g = \begin{bmatrix} \frac{\partial g}{\partial x} \\ \frac{\partial g}{\partial y} \end{bmatrix} = \begin{bmatrix} g_x \\ g_y \end{bmatrix}$$

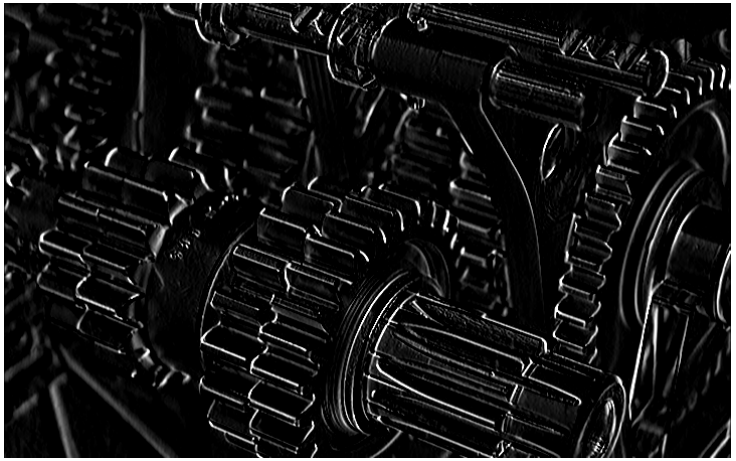
(2) 計算梯度的幅度和方向

(S_x, S_y) Gradient Vector

magnitude $= \sqrt{(S_x^2 + S_y^2)}$

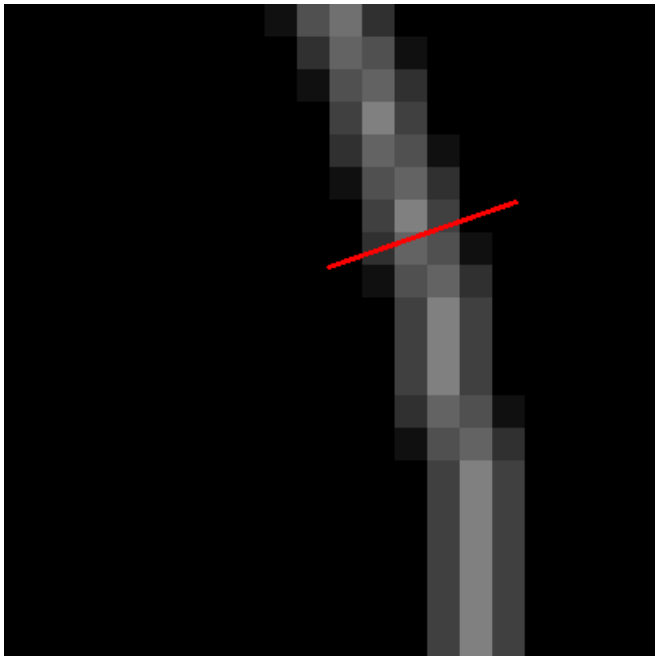
direction $= \theta = \tan^{-1} \dfrac{S_y}{S_x}$

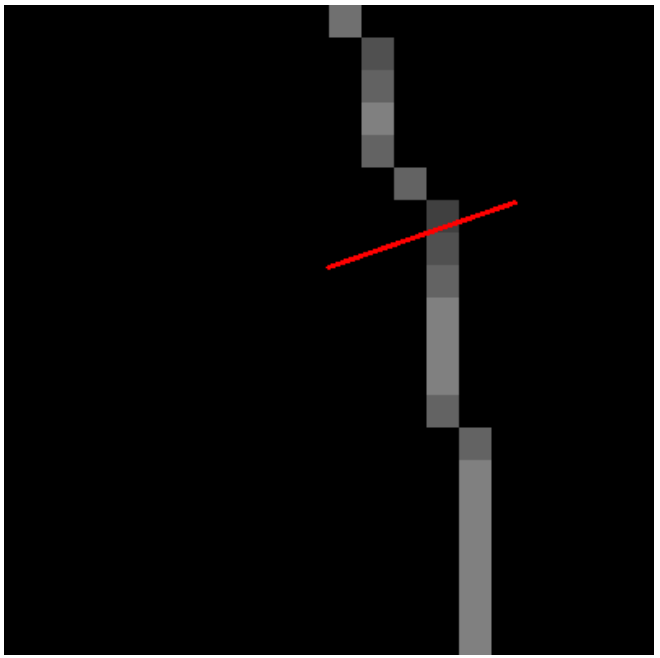




(3) Non-maximum suppression

這個步驟主要目的是要讓邊線變窄。





$$M(x,y)=\begin{cases}|\nabla S|(x,y) & \text{if } |\nabla S|(x,y)>|\Delta S|(x',y') \\ & \& \ |\Delta S|(x,y)>|\Delta S|(x'',y'') \\ 0 & \text{otherwise}\end{cases}$$

(4) Hysteresis Threashold

這個步驟使用2個閥值：高閥值與低閥值。

假定一個點M(x,y) 的亮度值為I

M(x,y) 為邊緣點　　I>HighThreadhold

M(x,y) 不是邊緣點　I<LowThreadhold

而在高閥值與低閥值之間的點則為不確定點，如果這些點和邊緣點有連接則設為邊緣點。

3. Canny function in OpenCV

```
void cv::Canny( InputArray _src, OutputArray _dst,
                double low_thresh, double high_thresh,
                int aperture_size=3, bool L2gradient =false)
```

Parameters:

image – single-channel 8-bit input image.

edges – output edge map; it has the same size and type as image .

threshold1 – first threshold for the hysteresis procedure.

threshold2 – second threshold for the hysteresis procedure.

apertureSize – aperture size for the Sobel() operator.

L2gradient – a flag, indicating whether a more accurate L_2 norm =\sqrt{(dI/dx)^2 + (dI/dy)^2} should be used to calculate the image gradient magnitude (L2gradient=true), or whether the default L_1 norm =|dI/dx|+|dI/dy| is enough (L2gradient=false).