視覺感測技術應用實務

直方圖匹配
第二組

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目錄

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- 獨特設計之處
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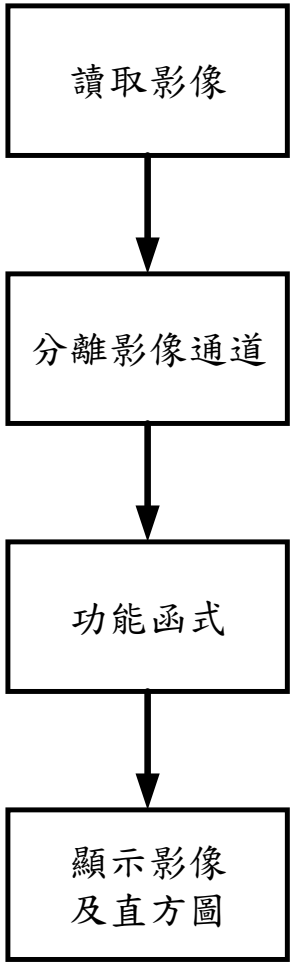
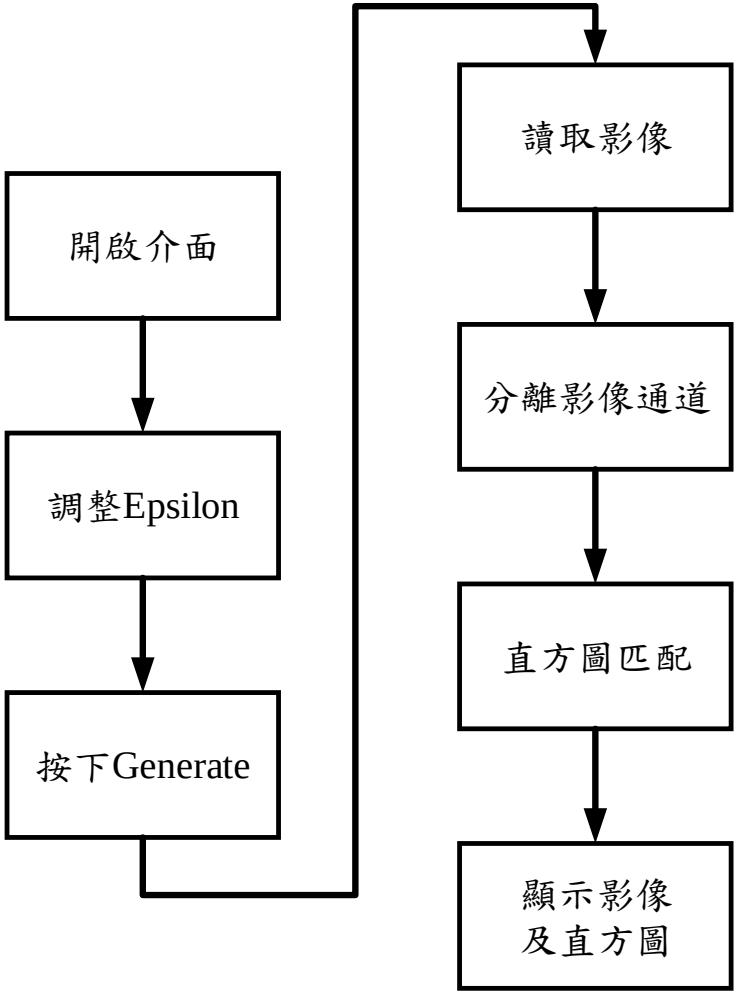
實現方法--動作流程圖

一般函式流程



直方圖匹配流程



實現方法--使用類別方法的類型

- 本次程式BaseIP和AlphaBlend的成員函式都使用static method，因為本次類別的成員函式不需要像是self或是cls等實例或類別的參考，所以使用static method可以比較簡明且有效率。
  - 簡明的部分在於不需要多接收一個無關緊要的引數
  - 效率在於一般的實例方法是bound method(是個object)且是在我們要使用他的時候才生成，這會多花費一點的時間，而靜態方法並不會

實現方法--程式(cv2IP.py)

BaseIP類別

```python
import cv2
import numpy as np
import enum
from matplotlib import pyplot as plt
import math
```

```python
class HistIP(BaseIP):

    def __init__(self):
        super().__init__()

    class ColorType(enum.IntEnum):
        USE_RGB = 1
        USE_HSV = 2
        USE_YUV = 3

    @staticmethod
    def ImBGR2Gray(SrcImg):
        DstImg = cv2.cvtColor(SrcImg, cv2.COLOR_BGR2GRAY)
        return DstImg

    @staticmethod
    def ImBGRA2BGR(SrcImg):
        DstImg = np.array(SrcImg[:,:,:3])
        return DstImg
```

實現方法--程式(cv2IP.py)

灰階直方圖

```
@staticmethod
def CalcGrayHist(SrcGray):
    GrayHist = cv2.calcHist([SrcGray], [0], None, [256], [0, 256])
    return GrayHist

@staticmethod
def ShowGrayHist(winname, GrayHist):
    plt.plot(GrayHist, "gray")
    plt.legend(["Gray"], loc="upper right")
    plt.title(winname)
    plt.xlabel("Bins")
    plt.ylabel("Number of pixels")
    plt.show()
```

實現方法--程式(cv2IP.py)

色彩直方圖

```
@staticmethod
def CalcColorHist(SrcColor):
    BlueHist = cv2.calcHist([SrcColor], [0], None, [256], [0, 256])
    GreenHist = cv2.calcHist([SrcColor], [1], None, [256], [0, 256])
    RedHist = cv2.calcHist([SrcColor], [2], None, [256], [0, 256])
    ColorHist = cv2.merge([BlueHist, GreenHist, RedHist])
    return ColorHist

@staticmethod
def ShowColorHist(winname, ColorHist):
    plt.plot(ColorHist[:,:,0], "b")
    plt.plot(ColorHist[:,:,1], "g")
    plt.plot(ColorHist[:,:,2], "r")
    plt.legend(["Blue", "Green", "Red"], loc="upper right")
    plt.title(winname)
    plt.xlabel("Bins")
    plt.ylabel("Number of pixels")
    plt.show()
```

實現方法--程式(cv2IP.py)

影像直方圖等化

```
@staticmethod
def MonoEqualize(SrcGray):
    EqualizedGray = cv2.equalizeHist(SrcGray)
    return EqualizedGray

@staticmethod
def ColorEqualize(SrcColor, CType = ColorType.USE_HSV):
    if CType == HistIP.ColorType.USE_RGB:
        EqualizedBlue = cv2.equalizeHist(SrcColor[:,:,0])
        EqualizedGreen = cv2.equalizeHist(SrcColor[:,:,1])
        EqualizedRed = cv2.equalizeHist(SrcColor[:,:,2])
        EqualizedColor = cv2.merge([EqualizedBlue, EqualizedGreen, EqualizedRed])
    elif CType == HistIP.ColorType.USE_HSV:
        SrcHSV = cv2.cvtColor(SrcColor, cv2.COLOR_BGR2HSV)
        EqualizedHSV = np.array(SrcHSV)
        EqualizedHSV[:,:,2] = cv2.equalizeHist(SrcHSV[:,:,2])
        EqualizedColor = cv2.cvtColor(EqualizedHSV, cv2.COLOR_HSV2BGR)
    elif CType == HistIP.ColorType.USE_YUV:
        SrcYUV = cv2.cvtColor(SrcColor, cv2.COLOR_BGR2YUV)
        EqualizedYUV = np.array(SrcYUV)
        EqualizedYUV[:,:,0] = cv2.equalizeHist(SrcYUV[:,:,0])
        EqualizedColor = cv2.cvtColor(EqualizedYUV, cv2.COLOR_YUV2BGR)
    return EqualizedColor
```

實現方法--程式(cv2IP.py)

PDF、CDF的直方圖

```python
@staticmethod
def CalPDFGrayHist(SrcImg):
    GrayHist = HistIP.CalcGrayHist(SrcImg)
    PDFGrayHist = GrayHist / SrcImg.size
    return PDFGrayHist

@staticmethod
def CalPDFColorHist(SrcImg):
    ColorHist = HistIP.CalcColorHist(SrcImg)
    PDFColorHist = ColorHist / SrcImg[:,:,0].size
    return PDFColorHist

@staticmethod
def CalCDFGrayHist(SrcImg):
    PDFGrayHist = HistIP.CalPDFGrayHist(SrcImg)
    CDFGrayHist = np.zeros(PDFGrayHist.shape)
    CDFGrayHist[0,:] = PDFGrayHist[0,:]
    for i in range(1,256,1):
        CDFGrayHist[i,:] = CDFGrayHist[i-1,:] + PDFGrayHist[i,:]
    return CDFGrayHist

@staticmethod
def CalCDFColorHist(SrcImg):
    PDFColorHist = HistIP.CalPDFColorHist(SrcImg)
    CDFColorHist = np.zeros(PDFColorHist.shape)
    CDFColorHist[0,:,:] = PDFColorHist[0,:,:]
    for i in range(1,256,1):
        CDFColorHist[i,:,:] = CDFColorHist[i-1,:,:] + PDFColorHist[i,:,:]
    return CDFColorHist
```

實現方法--程式(cv2IP.py)

LUT

```
@staticmethod
def CalculateLUT(SrcCDFHist, RefCDFHist, Epsilon = 0.05):
    LUT = np.zeros(256, dtype=np.int)
    Last = 0
    for i in range(256):
        for j in range(Last,256,1):
            if abs(RefCDFHist[j,0] - SrcCDFHist[i,0]) < Epsilon or RefCDFHist[j,0] > SrcCDFHist[i,0]:
                LUT[i] = j
                Last = j
                break
    return LUT
```

實現方法--程式(cv2IP.py)

RGB色彩空間的直方圖匹配

```
@staticmethod
def HistMatching(SrcImg, RefImg, Epsilon, CType = ColorType.USE_HSV):
    if CType == HistIP.ColorType.USE_RGB:
        #---------------------CDF---------------------#
        Src_CDFHist = HistIP.CalCDFColorHist(SrcImg)
        Ref_CDFHist = HistIP.CalCDFColorHist(RefImg)
        #---------------------LUT---------------------#
        BlueLUT = HistIP.CalculateLUT(Src_CDFHist[:,:,0], Ref_CDFHist[:,:,0], Epsilon)
        GreenLUT = HistIP.CalculateLUT(Src_CDFHist[:,:,1], Ref_CDFHist[:,:,1], Epsilon)
        RedLUT = HistIP.CalculateLUT(Src_CDFHist[:,:,2], Ref_CDFHist[:,:,2], Epsilon)
        LUT = cv2.merge([BlueLUT, GreenLUT, RedLUT])
        DstImg = np.array(SrcImg)
        for i in range(3):
            DstImg[:,:,i] = cv2.LUT(SrcImg[:,:,i], LUT[:,0,i])
```

實現方法--程式(cv2IP.py)

HSV色彩空間的直方圖匹配

```
elif CType == HistIP.ColorType.USE_HSV:
    SrcHSV = cv2.cvtColor(SrcImg, cv2.COLOR_BGR2HSV)
    RefHSV = cv2.cvtColor(RefImg, cv2.COLOR_BGR2HSV)
    #----------------------CDF----------------------#
    Src_CDFHist = HistIP.CalCDFGrayHist(SrcHSV[:,:,2])
    Ref_CDFHist = HistIP.CalCDFGrayHist(RefHSV[:,:,2])
    #----------------------LUT----------------------#
    LUT = HistIP.CalculateLUT(Src_CDFHist, Ref_CDFHist, Epsilon)
    DstHSV = np.array(SrcHSV)
    DstHSV[:,:,2] = cv2.LUT(SrcHSV[:,:,2], LUT)
    DstImg = cv2.cvtColor(DstHSV, cv2.COLOR_HSV2BGR)
```

實現方法--程式(cv2IP.py)

- YUV色彩空間的直方圖匹配

```
elif CType == HistIP.ColorType.USE_YUV:
    SrcYUV = cv2.cvtColor(SrcImg, cv2.COLOR_BGR2YUV)
    RefYUV = cv2.cvtColor(RefImg, cv2.COLOR_BGR2YUV)
    #----------------------CDF----------------------#
    Src_CDFHist = HistIP.CalCDFGrayHist(SrcYUV[:,:,0])
    Ref_CDFHist = HistIP.CalCDFGrayHist(RefYUV[:,:,0])
    #----------------------LUT----------------------#
    LUT = HistIP.CalculateLUT(Src_CDFHist, Ref_CDFHist, Epsilon)
    DstYUV = np.array(SrcYUV)
    DstYUV[:,:,0] = cv2.LUT(SrcYUV[:,:,0], LUT, Epsilon)
    DstImg = cv2.cvtColor(DstYUV, cv2.COLOR_YUV2BGR)
return DstImg
```

實現方法--程式(Project2.py)

主函式

```
import cv2
import numpy as np
import cv2IP
import tkinter as tk
```

創建HistIP的物件

```
def MyColorHistMatching(Epsilon):
    IP = cv2IP.HistIP()
```

- 使用物件導向方式來呼叫類別中的成員函式

實現方法--程式(Project2.py)

灰階影像

```
def MyShowGrayImage():
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/foreGroundAsset.png")
    if SrcImg.shape[2] == 4:
        F_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        F_BGR = np.array(SrcImg)
    F_Gray = IP.ImBGR2Gray(F_BGR)
    IP.ImWindow("ForeGround Gray Image")
    IP.ImShow("ForeGround Gray Image", F_Gray)
    cv2.waitKey(0)
    del IP
```

實現方法--程式(Project2.py)

灰階直方圖

```
def MyShowGrayHistogram():
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/foreGroundAsset.png")
    if SrcImg.shape[2] == 4:
        F_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        F_BGR = np.array(SrcImg)
    F_Gray = IP.ImBGR2Gray(F_BGR)
    F_Hist = IP.CalcGrayHist(F_Gray)
    IP.ShowGrayHist("ForeGround Gray Hist", F_Hist)
    del IP
```

實現方法--程式(Project2.py)

色彩直方圖

```
def MyShowColorHistogram():
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/foreGroundAsset.png")
    if SrcImg.shape[2] == 4:
        F_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        F_BGR = np.array(SrcImg)
    F_Hist = IP.CalcColorHist(F_BGR)
    IP.ShowColorHist("ForeGround Color Hist", F_Hist)
    del IP
```

實現方法--程式(Project2.py)

灰階直方圖等化

```
def MyMonoHistEqualize():
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/InputIm_1_FixdPoint.bmp")
    if SrcImg.shape[2] == 4:
        F_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        F_BGR = np.array(SrcImg)
    F_Gray = IP.ImBGR2Gray(F_BGR)
    F_Eq = IP.MonoEqualize(F_Gray)
    F_GrayHist = IP.CalcGrayHist(F_Gray)
    F_EqualizedHist = IP.CalcGrayHist(F_Eq)
    IP.ShowGrayHist("ForeGround Gray Hist", F_GrayHist)
    IP.ShowGrayHist("ForeGround Equalized Hist", F_EqualizedHist)
    IP.ImWindow("ForeGround Gray")
    IP.ImShow("ForeGround Gray", F_Gray)
    IP.ImWindow("ForeGround Gray Equalized")
    IP.ImShow("ForeGround Gray Equalized", F_Eq)
    cv2.waitKey(0)
    del IP
```

實現方法--程式(Project2.py)

色彩直方圖等化

```
def MyColorHistEqualize(CType):
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/InputIm_1_FixdPoint.bmp")
    if SrcImg.shape[2] == 4:
        F_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        F_BGR = np.array(SrcImg)
    F_Eq = IP.ColorEqualize(SrcImg, CType)
    F_ColorHist = IP.CalcColorHist(SrcImg)
    F_EqualizedHist = IP.CalcColorHist(F_Eq)
    IP.ShowColorHist("ForeGround Color Hist", F_ColorHist)
    IP.ShowColorHist("ForeGround Equalized Hist", F_EqualizedHist)
    IP.ImWindow("ForeGround Color")
    IP.ImShow("ForeGround Color", SrcImg)
    IP.ImWindow("ForeGround Color Equalized")
    IP.ImShow("ForeGround Color Equalized", F_Eq)
    cv2.waitKey(0)
    del IP
```

實現方法--程式(Project2.py)

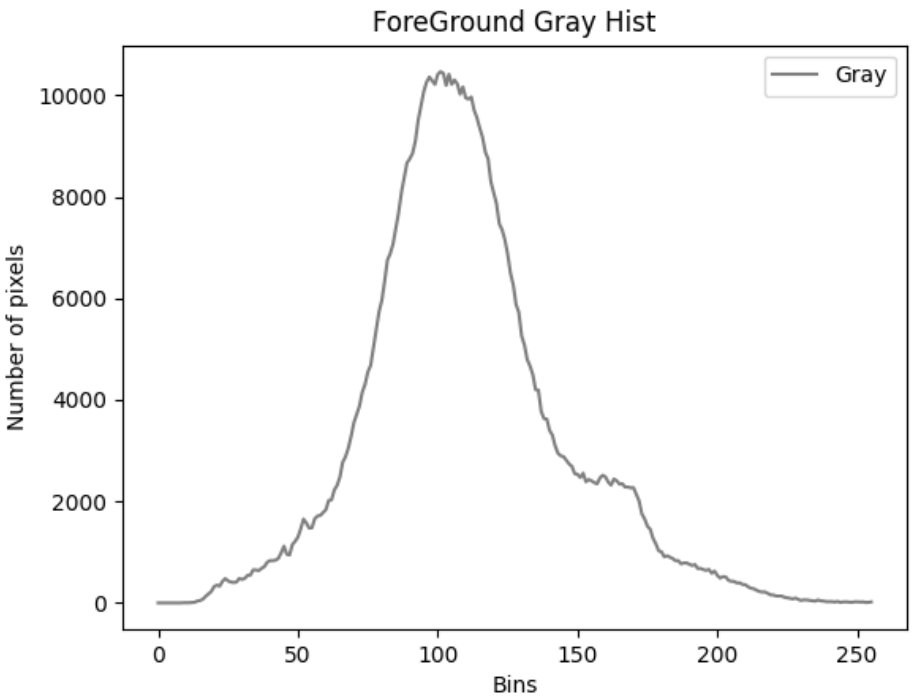
直方圖匹配

```
def MyColorHistMatching(Epsilon):
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/swan.png")
    RefImg = IP.ImRead("img/InputIm_1_FixdPoint.bmp")
    if SrcImg.shape[2] == 4:
        Src_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        Src_BGR = np.array(SrcImg)
    if RefImg.shape[2] == 4:
        Ref_BGR = IP.ImBGRA2BGR(RefImg)
    else:
        Ref_BGR = np.array(RefImg)
    OutImg = IP.HistMatching(Src_BGR, Ref_BGR, Epsilon, IP.ColorType.USE_HSV)
    IP.ImShow("Original Image", SrcImg)
    IP.ImShow("Reference Image", RefImg)
    IP.ImShow("Processed Image", OutImg)
    cv2.waitKey(0)
    cv2.destroyAllWindows()
    del IP
```

結果展示

灰階直方圖

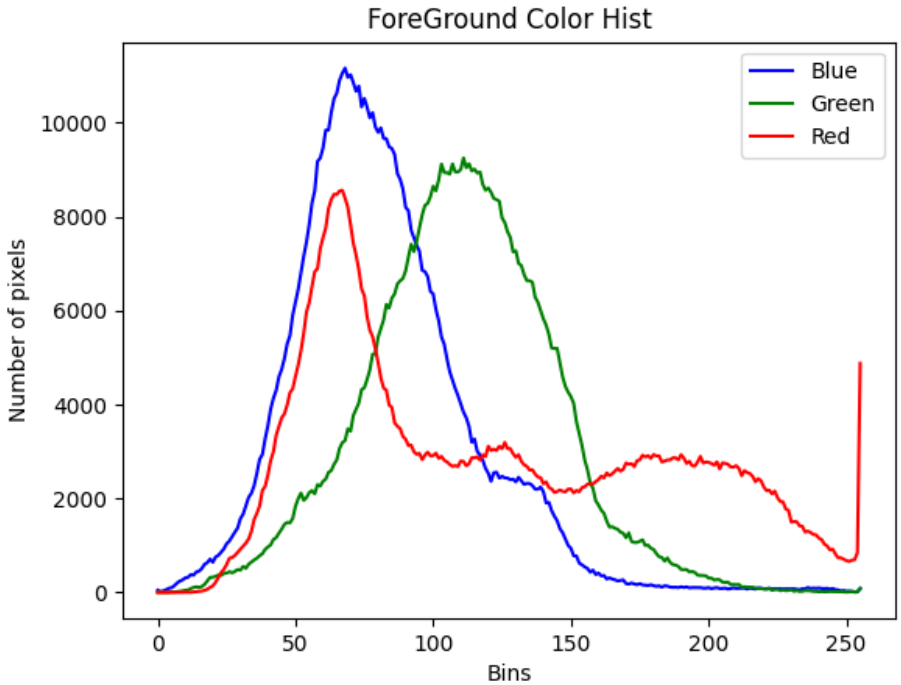

ForeGround Gray Image


ForeGround Gray Hist
Gray
Number of pixels
Bins
0
2000
4000
6000
8000
10000
0
50
100
150
200
250

結果展示

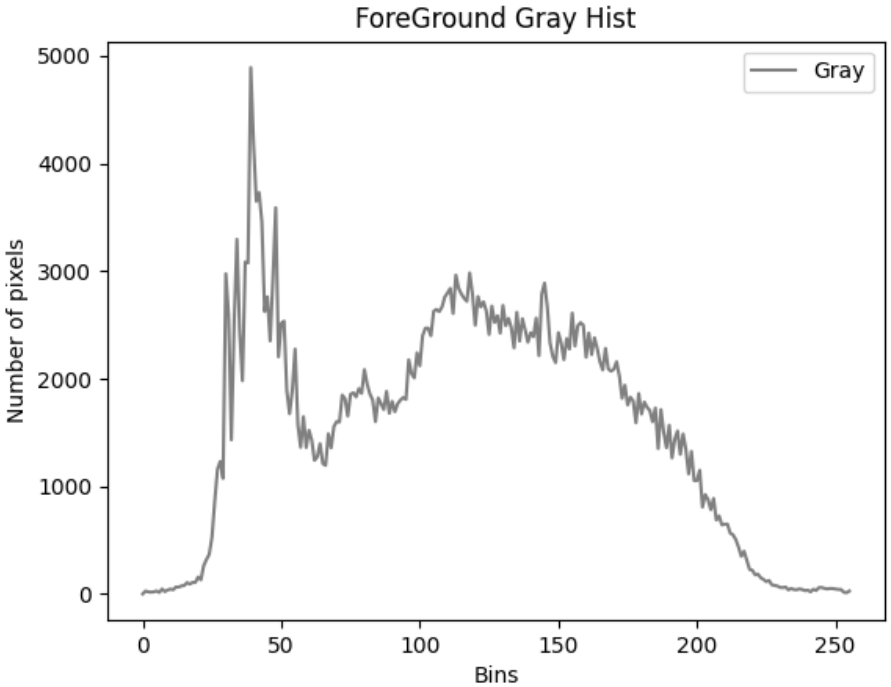
色彩直方圖


ForeGround Color Image


ForeGround Color Hist
Blue
Green
Red
Number of pixels
0
2000
4000
6000
8000
10000
0
50
100
150
200
250
Bins

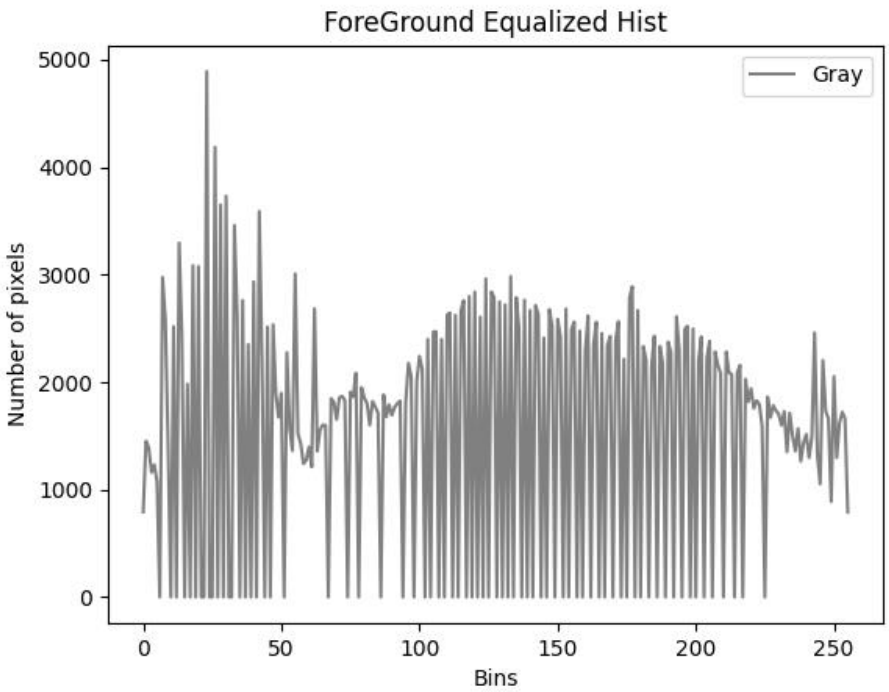
結果展示

灰階直方圖等化(來源圖)



結果展示

灰階直方圖等化(結果圖)



結果展示

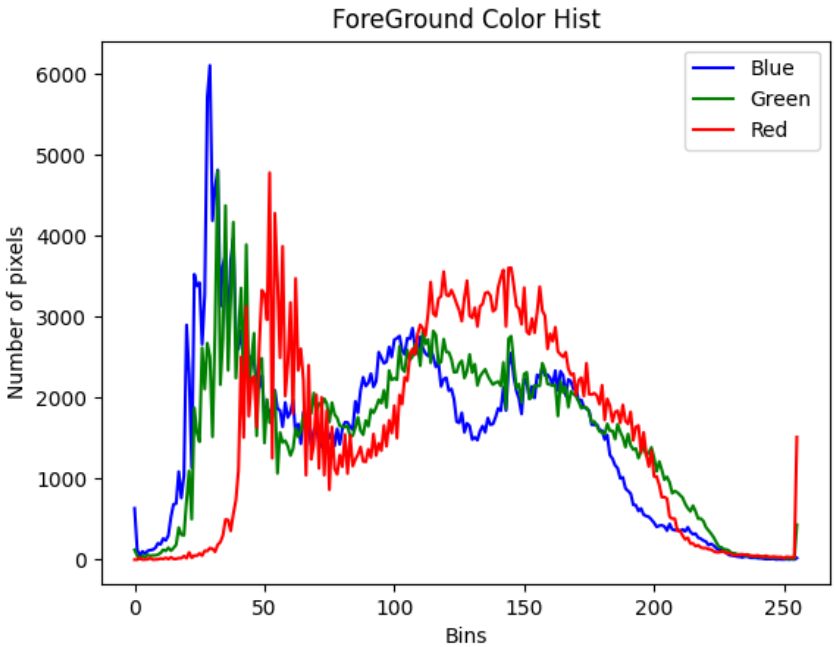
- 色彩直方圖等化(RGB色彩空間)

來源影像圖

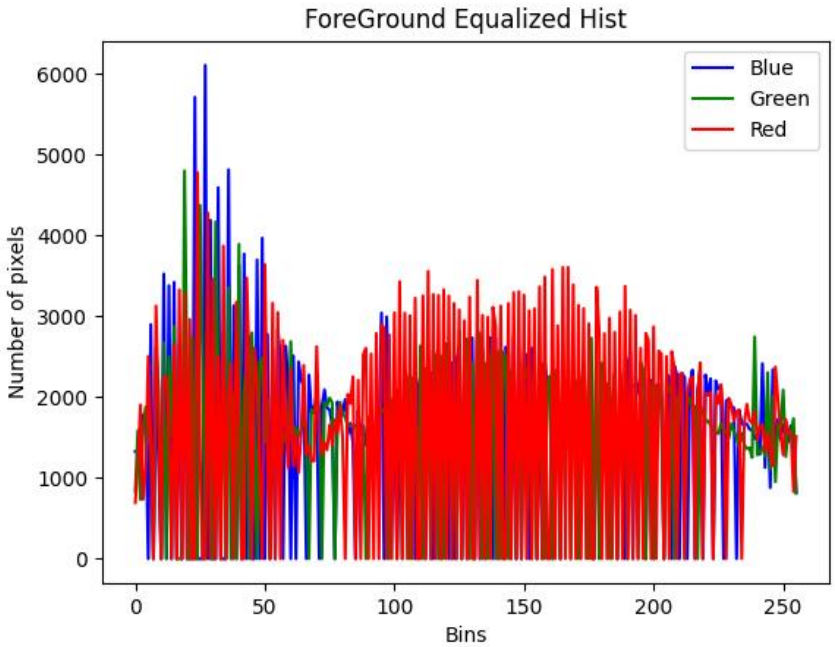
結果影像圖

結果展示

色彩直方圖等化(RGB色彩空間)



來源直方圖



結果直方圖

結果展示

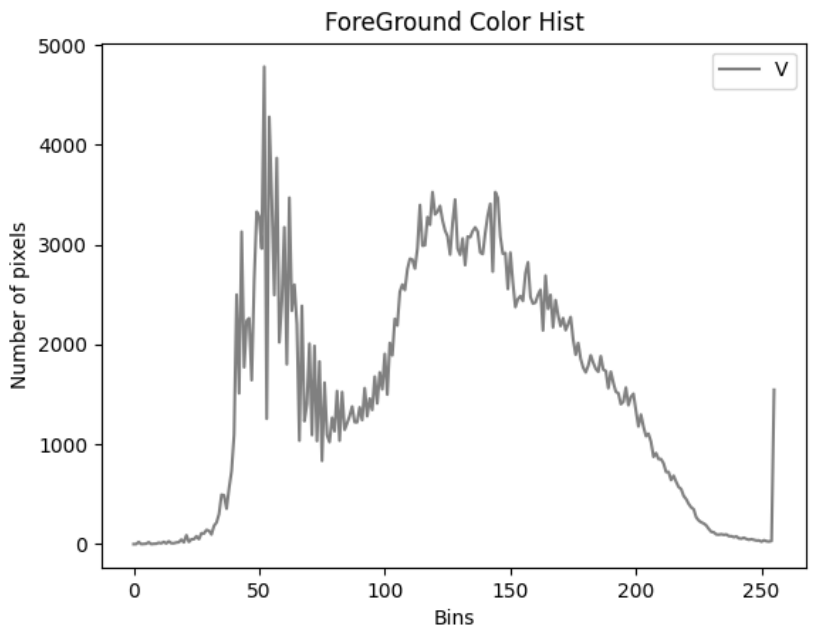
- 色彩直方圖等化(HSV色彩空間)

來源影像圖

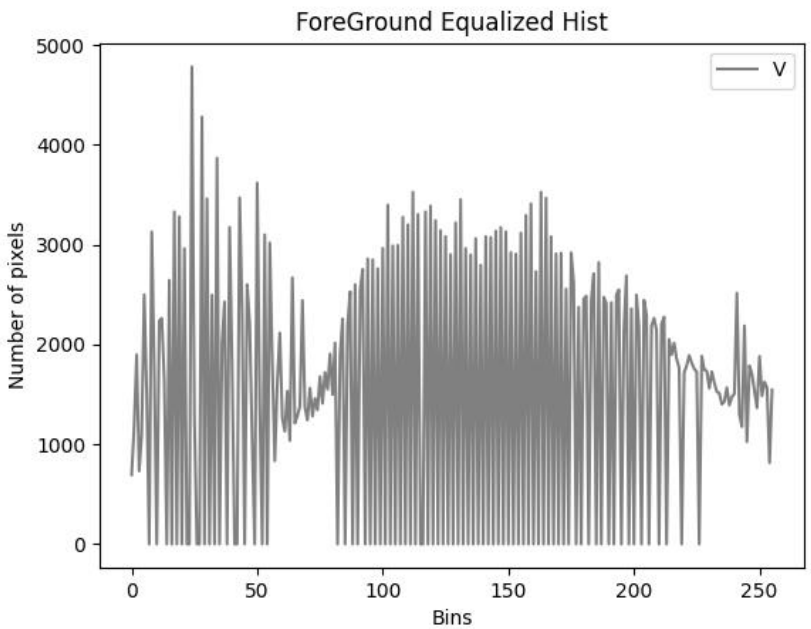
結果影像圖

結果展示

色彩直方圖等化(HSV色彩空間)



來源直方圖



結果直方圖

結果展示

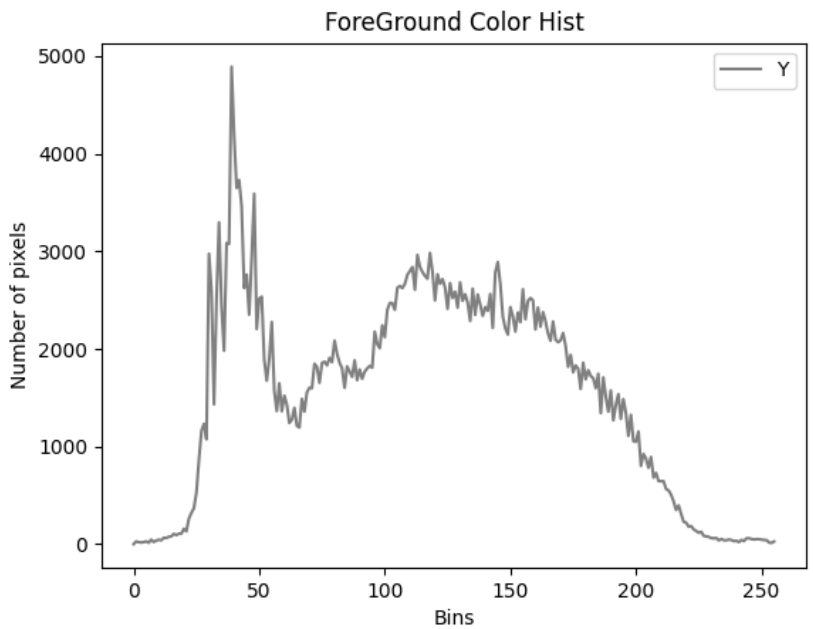
- 色彩直方圖等化(YUV色彩空間)

來源影像圖

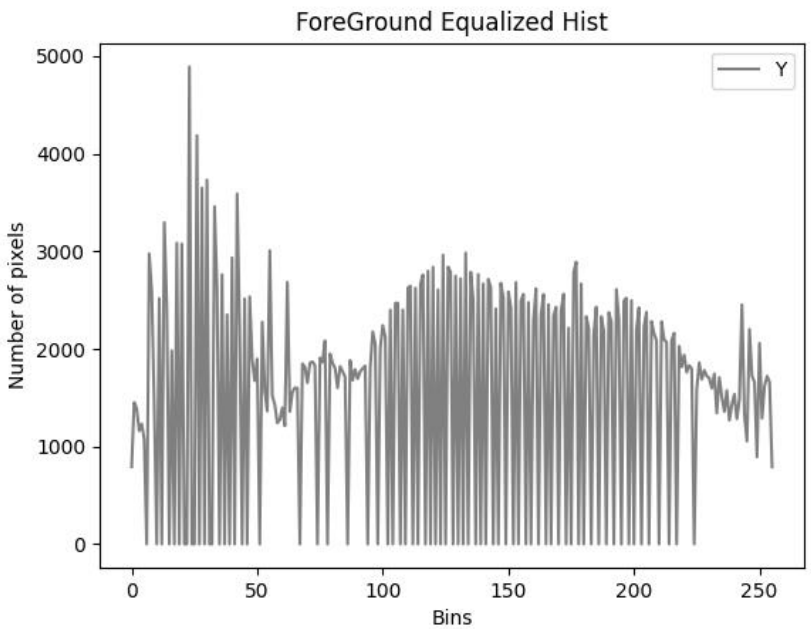
結果影像圖

結果展示

色彩直方圖等化(YUV色彩空間)



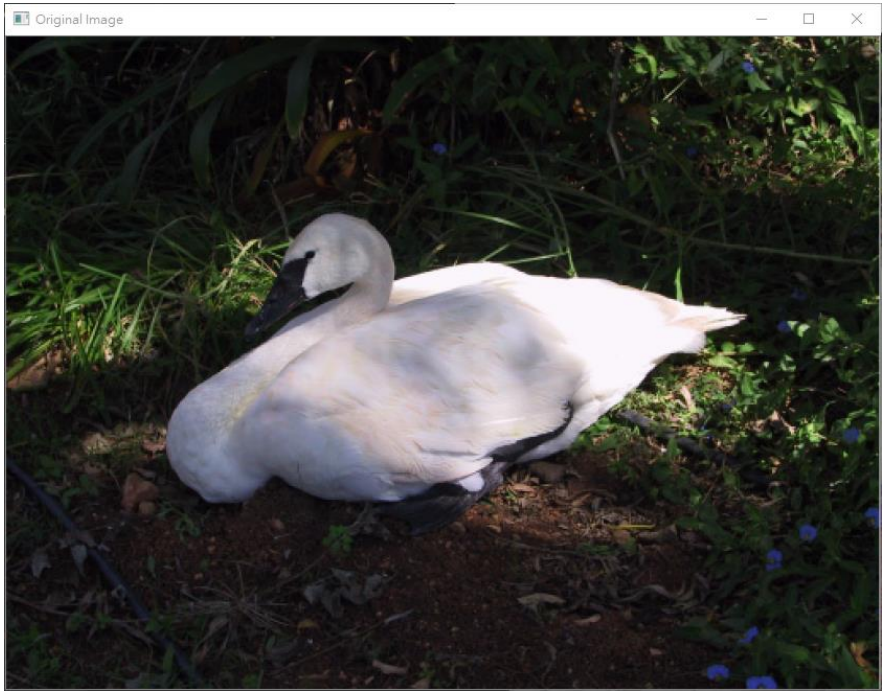
來源直方圖



結果直方圖

結果展示

色彩直方圖匹配

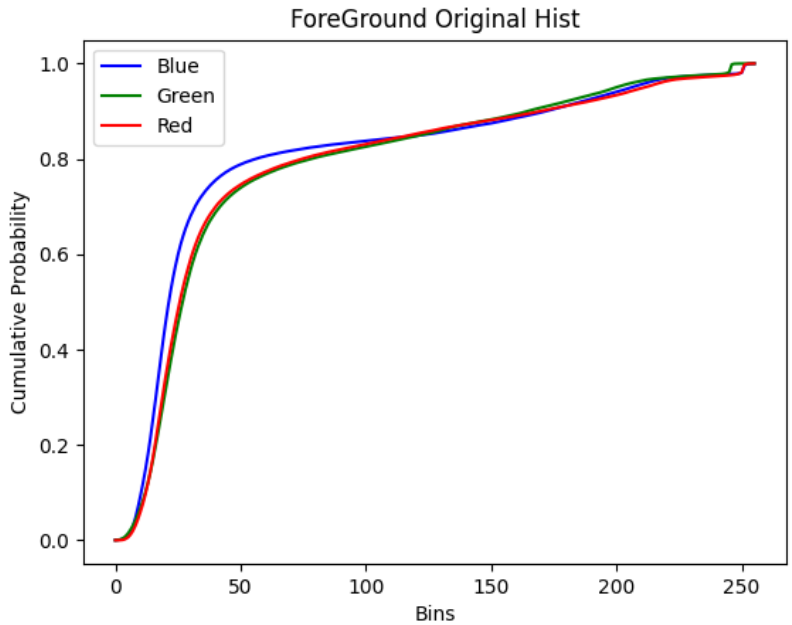


來源影像圖

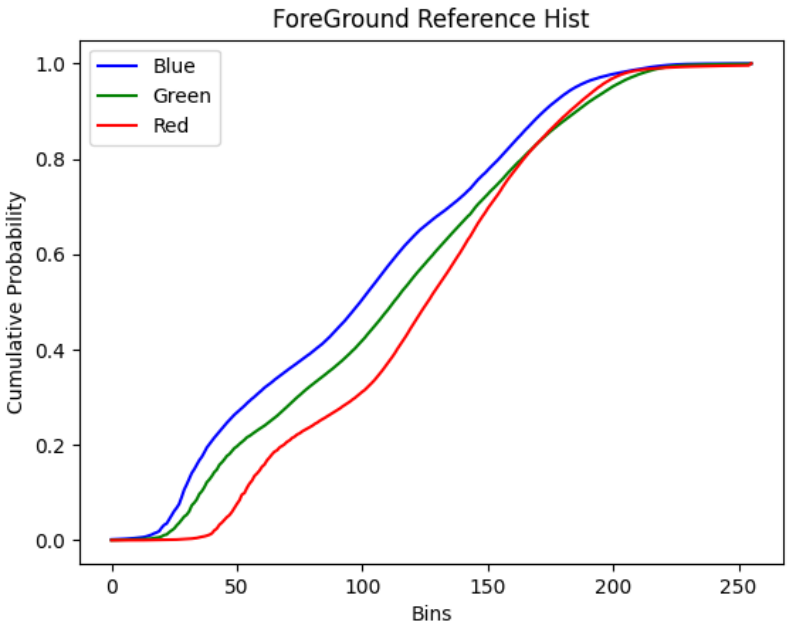
參考影像圖

結果展示

直方圖匹配(RGB色彩空間)



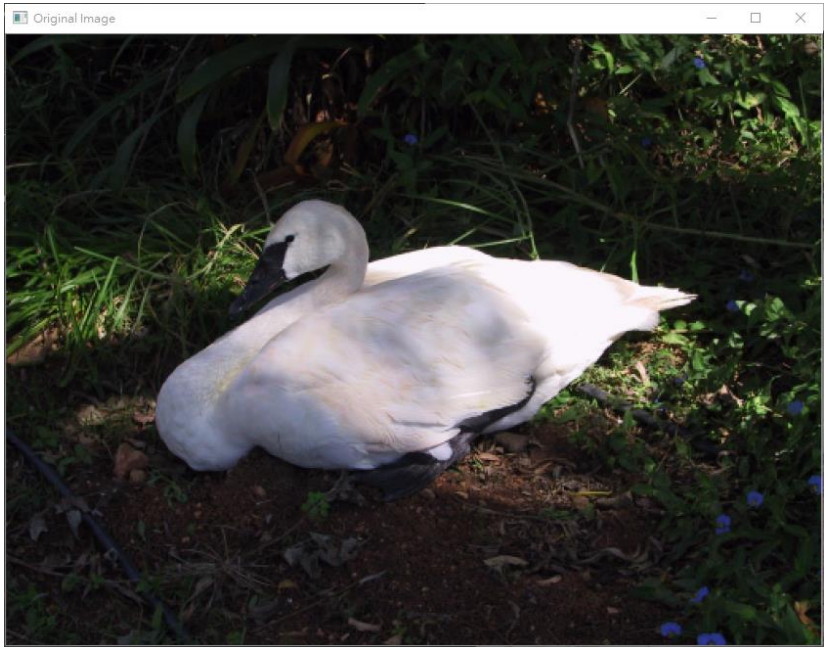
來源直方圖



參考直方圖

結果展示

- 直方圖匹配(RGB色彩空間)

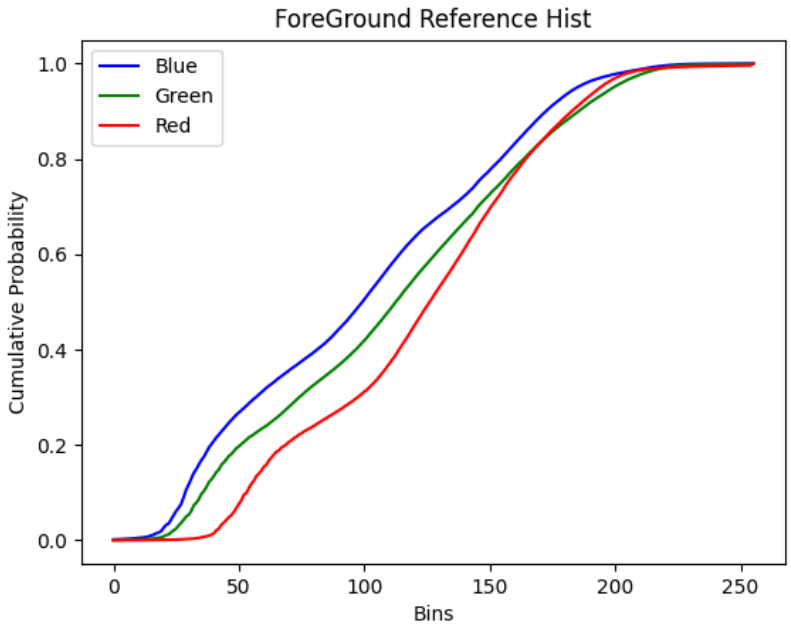


來源影像圖

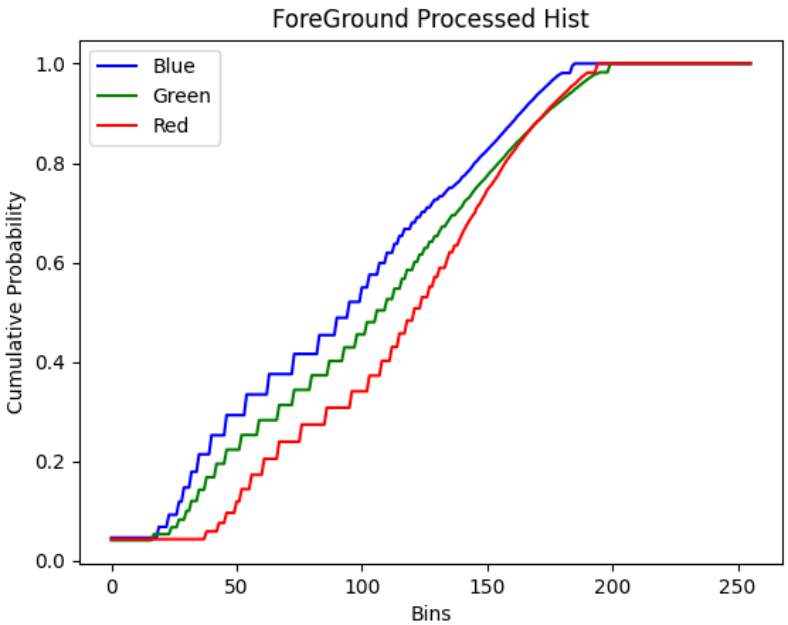
結果影像圖

結果展示

直方圖匹配(RGB色彩空間)



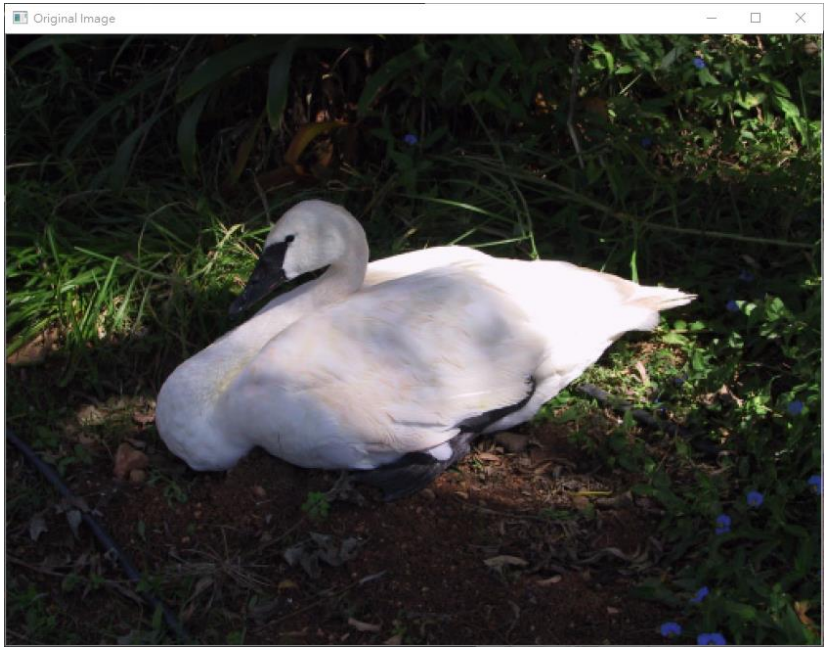
參考直方圖



結果直方圖

結果展示

- 直方圖匹配(HSV色彩空間)

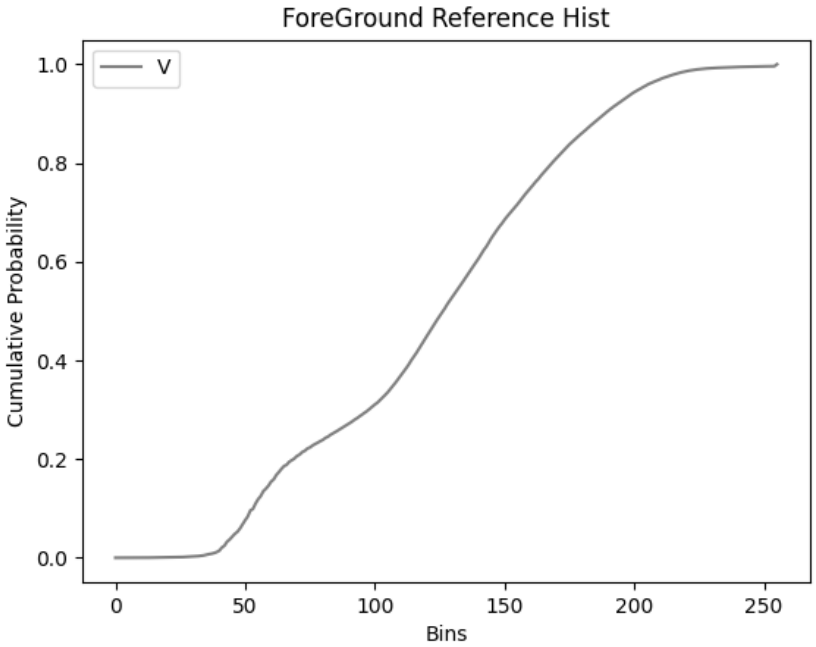


來源影像圖

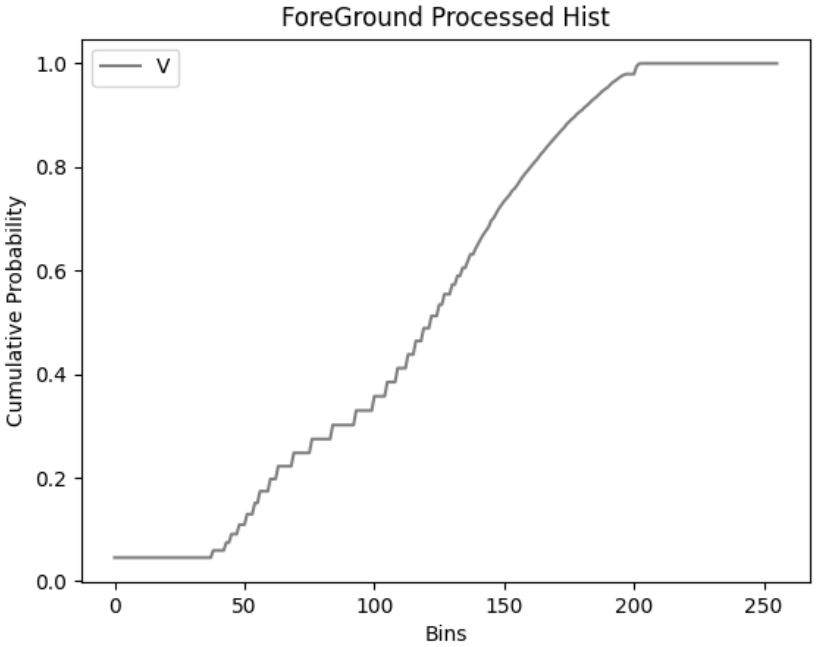
結果影像圖

結果展示

直方圖匹配(HSV色彩空間)



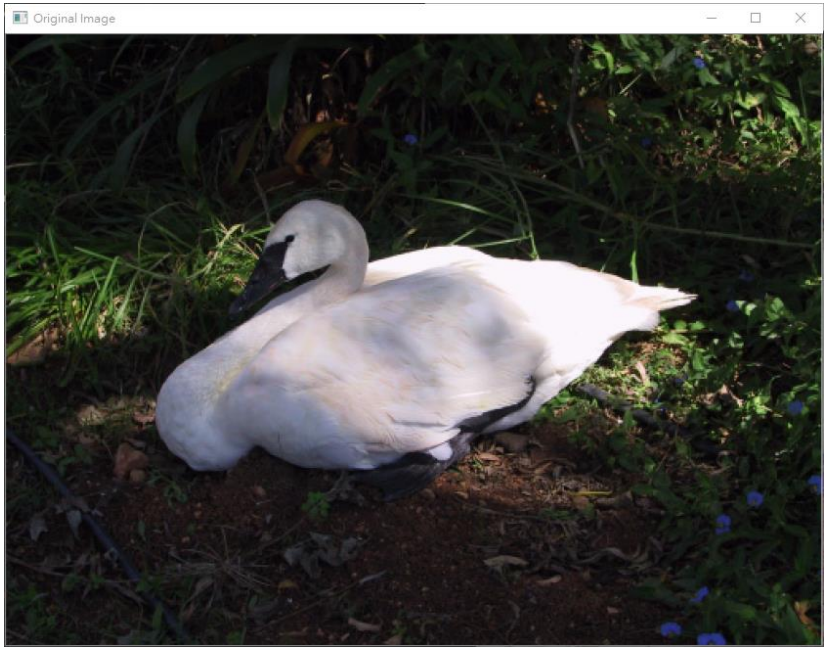
參考直方圖



結果直方圖

結果展示

- 直方圖匹配(YUV色彩空間)

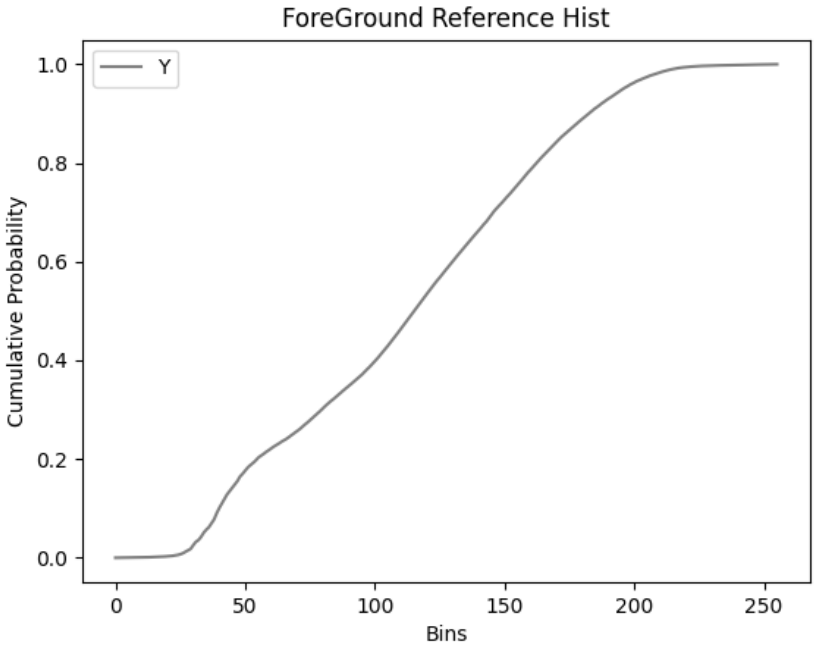


來源影像圖

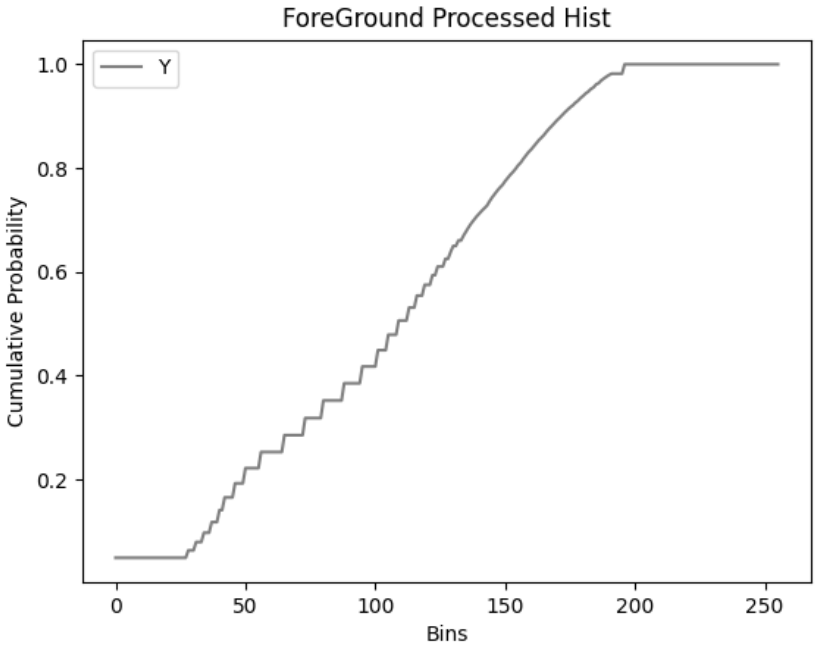
結果影像圖

結果展示

直方圖匹配(YUV色彩空間)



參考直方圖



結果直方圖

獨特設計之處

主函式

```python
if __name__ == '__main__':
    global GlobalEpsilon
    GlobalEpsilon = 0.0

    # 建立主視窗和 Frame（把元件變成群組的容器）
    window = tk.Tk()
    top_frame = tk.Frame(window)
    window.title('Hist Matching')
    window.geometry('320x140')
    window.configure(background='white')
    top_frame.pack()
    header_label = tk.Label(window, text='Hist Matching')
    header_label.pack()

    # 以下為 ChangeEpsilon_frame 群組
    ChangeEpsilon_frame = tk.Frame(window)
    ChangeEpsilon_frame.pack(side=tk.TOP)

    # 建立事件處理函式（event handler），透過元件 command 參數存取
    def ChangeEpsilon(epsilon):
        header_label.config(text='Epsilon of Hist Matching is ' + epsilon)
        global GlobalEpsilon
        GlobalEpsilon = float(epsilon)

    # 將元件分為Scale 加入主視窗
    scale = tk.Scale(ChangeEpsilon_frame, label='epsilon', from_=0.0, to=0.1, orient=tk.HORIZONTAL,length=200, showvalue=1, tickinterval=2, resolution=0.01, command=ChangeEpsilon)
    scale.pack()
```

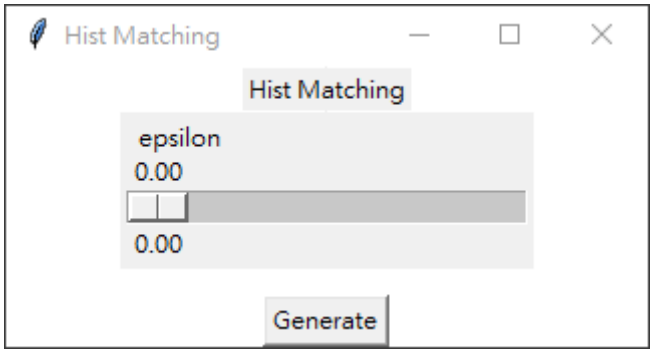
獨特設計之處

主函式

```
# 建立事件處理函式（event handler），透過元件 command 參數存取
def HistMatching():
    MyColorHistMatching(GlobalEpsilon)

# 將元件分為Scale 加入主視窗
bottom_frame = tk.Frame(window)
bottom_frame.pack(side=tk.BOTTOM)
# 以下為 bottom 群組
bottom_button = tk.Button(bottom_frame, text='Generate', fg='black', command=HistMatching)
# 讓系統自動擺放元件（靠下方）
bottom_button.pack()

# 運行主程式
window.mainloop()
```

獨特設計之處

調整Epsilon




```python
@staticmethod
def CalculateLUT(SrcCDFHist, RefCDFHist, Epsilon = 0.05):
    LUT = np.zeros(256, dtype=np.int)
    Last = 0
    for i in range(256):
        for j in range(Last,256,1):
            if abs(RefCDFHist[j,0] - SrcCDFHist[i,0]) < Epsilon or RefCDFHist[j,0] > SrcCDFHist[i,0]:
                LUT[i] = j
                Last = j
                break
    return LUT
```

獨特設計之處(RGB色彩空間)

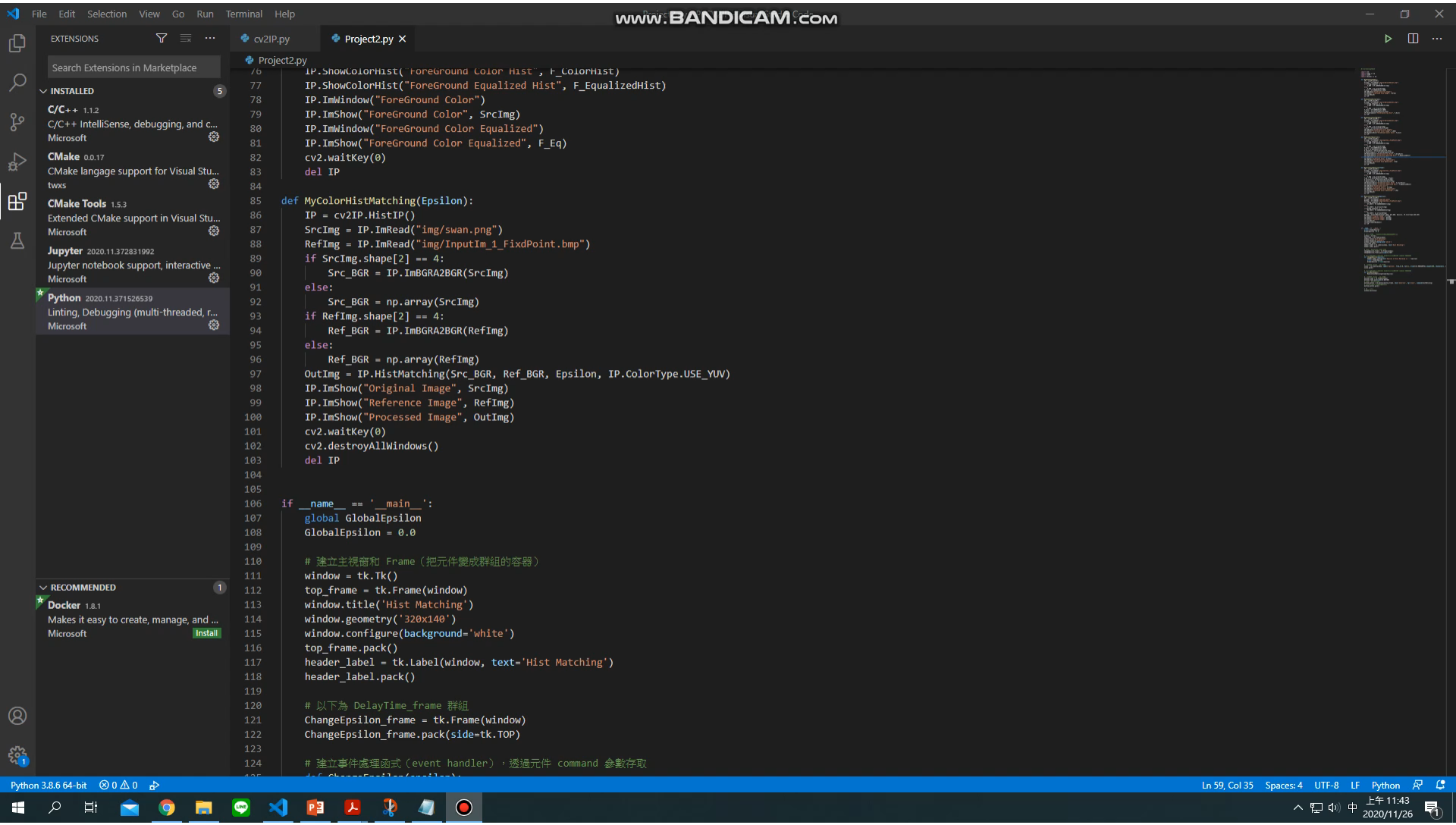
```python
    SrcImg = IP.ImRead("img/InputIm_1_FixdPoint.bmp")
    if SrcImg.shape[2] == 4:
        F_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        F_BGR = np.array(SrcImg)
    F_Eq = IP.ColorEqualize(SrcImg, CType)
    F_ColorHist = IP.CalcColorHist(SrcImg)
    F_EqualizedHist = IP.CalcColorHist(F_Eq)
    IP.ShowColorHist("ForeGround Color Hist", F_ColorHist)
    IP.ShowColorHist("ForeGround Equalized Hist", F_EqualizedHist)
    IP.ImWindow("ForeGround Color")
    IP.ImShow("ForeGround Color", SrcImg)
    IP.ImWindow("ForeGround Color Equalized")
    IP.ImShow("ForeGround Color Equalized", F_Eq)
    cv2.waitKey(0)
    del IP

def MyColorHistMatching(Epsilon):
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/swan.png")
    RefImg = IP.ImRead("img/InputIm_1_FixdPoint.bmp")
    if SrcImg.shape[2] == 4:
        Src_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        Src_BGR = np.array(SrcImg)
    if RefImg.shape[2] == 4:
        Ref_BGR = IP.ImBGRA2BGR(RefImg)
    else:
        Ref_BGR = np.array(RefImg)
    OutImg = IP.HistMatching(Src_BGR, Ref_BGR, Epsilon, IP.ColorType.USE_RGB)
    IP.ImShow("Original Image", SrcImg)
    IP.ImShow("Reference Image", RefImg)
    IP.ImShow("Processed Image", OutImg)
    cv2.waitKey(0)
    cv2.destroyAllWindows()
    del IP


if __name__ == '__main__':
    global GlobalEpsilon
    GlobalEpsilon = 0.0

    # 建立主視窗和 Frame（把元件變成群組的容器）
    window = tk.Tk()
    top_frame = tk.Frame(window)
    window.title('Hist Matching')
    window.geometry('320x140')
    window.configure(background='white')
    top_frame.pack()
```

獨特設計之處(HSV色彩空間)

cv2IP.py | Project2.py

```python
    F_ColorHist = IP.CalcColorHist(SrcImg)
    F_EqualizedHist = IP.CalcColorHist(F_Eq)
    IP.ShowColorHist("ForeGround Color Hist", F_ColorHist)
    IP.ShowColorHist("ForeGround Equalized Hist", F_EqualizedHist)
    IP.ImWindow("ForeGround Color")
    IP.ImShow("ForeGround Color", SrcImg)
    IP.ImWindow("ForeGround Color Equalized")
    IP.ImShow("ForeGround Color Equalized", F_Eq)
    cv2.waitKey(0)
    del IP

def MyColorHistMatching(Epsilon):
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/swan.png")
    RefImg = IP.ImRead("img/InputIm_1_FixdPoint.bmp")
    if SrcImg.shape[2] == 4:
        Src_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        Src_BGR = np.array(SrcImg)
    if RefImg.shape[2] == 4:
        Ref_BGR = IP.ImBGRA2BGR(RefImg)
    else:
        Ref_BGR = np.array(RefImg)
    OutImg = IP.HistMatching(Src_BGR, Ref_BGR, Epsilon, IP.ColorType.USE_HSV)
    IP.ImShow("Original Image", SrcImg)
    IP.ImShow("Reference Image", RefImg)
    IP.ImShow("Processed Image", OutImg)
    cv2.waitKey(0)
    cv2.destroyAllWindows()
    del IP


if __name__ == '__main__':
    global GlobalEpsilon
    GlobalEpsilon = 0.0

    # 建立主視窗和 Frame（把元件變成群組的容器）
    window = tk.Tk()
    top_frame = tk.Frame(window)
    window.title('Hist Matching')
    window.geometry('320x140')
    window.configure(background='white')
    top_frame.pack()
    header_label = tk.Label(window, text='Hist Matching')
    header_label.pack()

    # 以下為 DelayTime_frame 群組
    ChangeEpsilon_frame = tk.Frame(window)
    ChangeEpsilon_frame.pack(side=tk.TOP)
```

獨特設計之處(YUV色彩空間)



```python
    IP.ShowColorHist("ForeGround Color Hist", F_ColorHist)
    IP.ShowColorHist("ForeGround Equalized Hist", F_EqualizedHist)
    IP.ImWindow("ForeGround Color")
    IP.ImShow("ForeGround Color", SrcImg)
    IP.ImWindow("ForeGround Color Equalized")
    IP.ImShow("ForeGround Color Equalized", F_Eq)
    cv2.waitKey(0)
    del IP

def MyColorHistMatching(Epsilon):
    IP = cv2IP.HistIP()
    SrcImg = IP.ImRead("img/swan.png")
    RefImg = IP.ImRead("img/InputIm_1_FixdPoint.bmp")
    if SrcImg.shape[2] == 4:
        Src_BGR = IP.ImBGRA2BGR(SrcImg)
    else:
        Src_BGR = np.array(SrcImg)
    if RefImg.shape[2] == 4:
        Ref_BGR = IP.ImBGRA2BGR(RefImg)
    else:
        Ref_BGR = np.array(RefImg)
    OutImg = IP.HistMatching(Src_BGR, Ref_BGR, Epsilon, IP.ColorType.USE_YUV)
    IP.ImShow("Original Image", SrcImg)
    IP.ImShow("Reference Image", RefImg)
    IP.ImShow("Processed Image", OutImg)
    cv2.waitKey(0)
    cv2.destroyAllWindows()
    del IP


if __name__ == '__main__':
    global GlobalEpsilon
    GlobalEpsilon = 0.0

    # 建立主視窗和 Frame（把元件變成群組的容器）
    window = tk.Tk()
    top_frame = tk.Frame(window)
    window.title('Hist Matching')
    window.geometry('320x140')
    window.configure(background='white')
    top_frame.pack()
    header_label = tk.Label(window, text='Hist Matching')
    header_label.pack()

    # 以下為 DelayTime_frame 群組
    ChangeEpsilon_frame = tk.Frame(window)
    ChangeEpsilon_frame.pack(side=tk.TOP)

    # 建立事件處理函式（event handler），透過元件 command 參數存取
```

組員分工表

組員	工作分配比重	內容
李宗晏	100%	程式、報告

Thanks for your attention