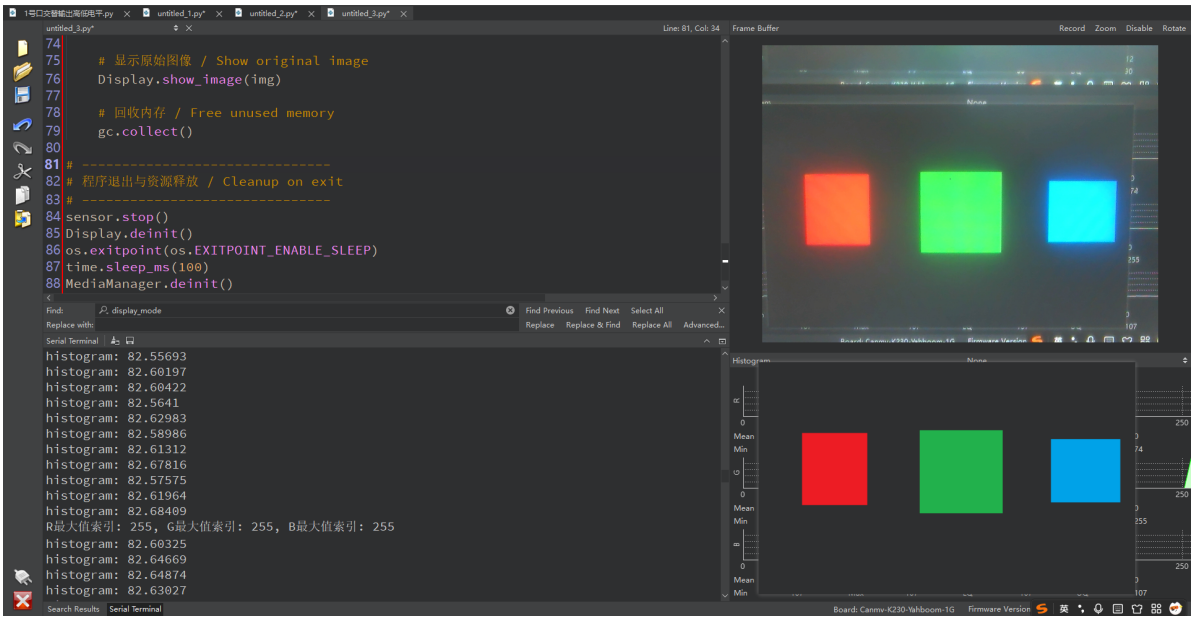
Image Color Histogram

Example Results

Run this section's example code [Source Code/06.cv_lite/19.rgb888_calc_histogram.py]

In this section, we will use the `cv_lite` extension module to implement image histogram calculation for RGB888 format on an embedded device.



Principle Explanation

What is an Image Histogram?

An image histogram is a statistical tool used to represent the intensity distribution of image pixels. It describes the brightness, contrast, and color distribution of an image by counting the frequency of occurrence of each pixel value in the image. For color images such as RGB888, histograms are typically calculated separately for each color channel (red, green, and blue).

- **Basic concepts**:
  - Pixel value range: For 8-bit images, pixel values range from 0 (black) to 255 (white).

    - Histogram representation: An array or chart where the x-axis represents the pixel value (0~255) and the y-axis represents the frequency of occurrence of the pixel value.
    - For RGB888 images, the histogram is a 3-channel array (256 bins per channel) that counts the pixel distribution of the R, G, and B channels respectively.
- **Calculation process**:
    - Traverse the image pixels and count the number of each pixel value in each channel.
    - The result is an array of shape 3x256 (for example, hist[0] is the B channel, hist[1] is the G channel, and hist[2] is the R channel).
- **Application**:
    - **Image characteristics analysis**: Helps evaluate the brightness of the image (histogram leaning to the left indicates dark, and leaning to the right indicates bright) and contrast (uniform distribution indicates high contrast).
    - **Image enhancement**: Perform histogram equalization based on the histogram to improve image quality.
    - **In this code**: After calculating the histogram, the maximum index of each channel (i.e., the bin with the highest pixel value frequency) is extracted to monitor the image's color distribution or abnormalities.

Histograms are a fundamental tool in image processing and are often used in preprocessing stages such as automatic exposure adjustment or object detection.

Code Overview

Importing Modules

```
import time, os, sys, gc
from machine import Pin
from media.sensor import * # Camera interface
from media.display import * # Display interface
from media.media import * # Media manager
import _thread
import cv_lite # cv_lite extension module, including the histogram function / C extension module for image processing
import ulab.numpy as np # ulab array module / NumPy-like ndarray for MicroPython
```

Setting the Image Size

```
image_shape = [480, 640] # Height x Width / Height x Width
```

Define the image resolution to 480x640 (height x width). The camera and display modules will be initialized based on this size later.

Initialize the camera (RGB888 format)

```
sensor = Sensor(id=2, width=1280, height=960, fps=90)
sensor.reset()
sensor.set_framesize(width=image_shape[1], height=image_shape[0])
sensor.set_pixformat(Sensor.RGB888) # Set pixel format to RGB888
```

- Initialize the camera, set the resolution to 1280x960 and the frame rate to 90 FPS.
- Resize the output frame to 640x480 and set it to RGB888 format (three-channel color image, suitable for histogram calculation of color images).

Initialize the display module

```
Display.init(Display.ST7701, width=image_shape[1], height=image_shape[0],
to_ide=True, quality=100)
```

Initialize the display module, using the ST7701 driver chip, with a resolution consistent with the image size. `to_ide=True` indicates that the image will be simultaneously transmitted to the IDE for virtual display, and `quality=100` sets the image transmission quality to the highest.

Initialize the media manager and start the camera

```
MediaManager.init()
sensor.run()
```

Initialize the media resource manager and start the camera to capture the image stream.

Image Processing and Histogram Calculation

```
clock = time.clock()
count = 0

while True:
    count += 1
    clock.tick()  # Record the start time of the current frame

    # Capture a frame
    img = sensor.snapshot()
    img_np = img.to_numpy_ref() # Get an RGB888 image reference (HWC)

    # Calculate the RGB histogram using cv_lite (returns a 3x256 array)
    # Calculate RGB888 histogram using cv_lite (3x256 array)
    hist = cv_lite.rgb888_calc_histogram(image_shape, img_np)

    # Print the maximum bin index every 30 frames
    if count == 30:
        r_hist = hist[2] # R channel / Red channel
        g_hist = hist[1] # G channel / Green channel
        b_hist = hist[0] # B channel / Blue channel
        r_max = int(np.argmax(r_hist)) # R maximum index / Max index of red
channel
        g_max = int(np.argmax(g_hist)) # G maximum index / Max index of green
channel
        b_max = int(np.argmax(b_hist)) # B maximum index / Max index of blue
channel
        print(f"R maximum index: {r_max}, G maximum index: {g_max}, B maximum
index: {b_max}")
        count = 0

    # Print current frame rate / Print FPS
    print("histogram:", clock.fps())

    # Show original image / Show original image
    Display.show_image(img)

    # Reclaim memory / Free unused memory
    gc.collect()
```

- **Image Capture**: Acquire an image frame using `sensor.snapshot()` and convert it to a NumPy array reference using `to_numpy_ref()`.
- **Histogram Calculation**: Call `cv_lite.rgb888_calc_histogram()` to calculate the RGB histogram of the image, returning a 3x256 array (256 bins per channel).
- **Data Analysis**: Every 30 frames, use `np.argmax()` to find the maximum index (i.e., the pixel value with the highest frequency) of each channel's histogram and print it out.
- **Display and Output**: Display the original image, print the current frame rate, and perform garbage collection to manage memory.

Resource Release

```
sensor.stop()
Display.deinit()
os.exitpoint(os.EXITPOINT_ENABLE_SLEEP)
time.sleep_ms(100)
MediaManager.deinit()
```

Parameter Tuning Notes

There are no explicitly tunable parameters (such as thresholds or kernel sizes) in this code. If performance needs to be optimized, you can adjust the counter (such as the interval of `count == 30`) in the main loop to control the printing frequency, but this does not directly affect the histogram calculation.