Aim: Processing image with opencv3

Objective: To conversion between different color spaces.The fourier transformation, high pass filter and low pass filter.

Theory:

Conversion between different color spaces:

Color spaces are mathematical models used to represent colors in images. Converting between different color spaces allows us to manipulate and analyze images more effectively based on specific requirements. Some common color spaces include RGB (Red, Green, Blue), CMYK (Cyan, Magenta, Yellow, Black), HSV (Hue, Saturation, Value), and LAB. Understanding the properties and appropriate use of each color space is vital for tasks like color correction, image segmentation, and object recognition.

Color Spaces are as follow:

1. Grayscale

A grayscale picture just needs intensity information - how bright is a particular pixel. The higher the value, the greater the intensity. Current displays support 256 distinct shades of gray. Each one is just a little bit lighter than the previous one!So for a grayscale image, all you need is one single byte for each pixel. One byte (or 8-bits) can store a value from 0 to 255, and thus you'd cover all possible shades of gray.So in the memory, a grayscale image is represented by a two dimensional array of bytes. The size of the array being equal to the height and width of the image. Technically, this array is a "channel". So, a grayscale image has only one channel. And this channel represents the intensity of whites.

2. RGB and BGR color space

The RGB color model is implemented in different ways, depending on the capabilities of the system used. The most common incarnation in general use as of 2021 is the 24-bit implementation, with 8 bits, or 256 discrete levels of color per channel. Any color space based on such a 24-bit RGB model is thus limited to a range of $256\times256\times256 \approx 16.7$ million colors.

BGR is the same, except the order of areas is reversed. Red occupies the least significant area, Green the second (still), and Blue the third.On some platforms a BGR model is used. However, for most, like your computer, RGB is used OpenCV supports BGR model.

3. HSL and HSV Color Space

HSL (Hue, Saturation, Lightness) and HSV (Hue, Saturation, Value) are two popular color spaces commonly used in machine vision and image processing. Both color spaces are derived from the RGB color model, but they represent colors in different ways, making them advantageous for certain applications.

HSL (Hue, Saturation, Lightness) is another color space commonly used in computer graphics, image processing, and computer vision. Like HSV, it is also derived from the RGB color model and provides a different way to represent and manipulate colors, focusing on three main components: hue, saturation, and lightness.

HSV is commonly used in machine vision for color-based object detection and tracking. By fixing the hue and adjusting the saturation and value thresholds, it becomes easier to segment objects of a specific color from the background, even under varying lighting conditions. HSV is also more intuitive for describing and working with color ranges, making it well-suited for applications such as image thresholding and region-of-interest extraction.

Conversions can be done as follow:

1. RGB to Grayscale: Converting RGB (Red, Green, Blue) images to grayscale reduces the image to a single channel, representing the intensity of each pixel. Grayscale images are useful for tasks that do not require color information, such as edge detection, image thresholding, and image segmentation.
2. RGB to HSV/HSL: Converting RGB images to HSV (Hue, Saturation, Value) or HSL (Hue, Saturation, Lightness) allows for better color-based image analysis. These color spaces separate the color information from brightness, making it easier to extract specific color ranges or identify objects based on color characteristics.

Color space conversion plays a crucial role in machine vision tasks, enabling the selection of the most suitable color representation for specific image analysis objectives. By transforming colors between different color spaces, computer vision algorithms can extract relevant features, enhance image quality, and facilitate subsequent processing steps effectively.

The fourier transformation

When we work in image processing, Fourier transform is an important image processing tool which is used to decompose an image into the frequency domain. The input image of the Fourier transform is the spatial domain(x,y) equivalent. The output of the Fourier transform represents the image in the frequency domain.

In the frequency domain image, each point represents a particular frequency contained in the spatial domain image. if an image has more high-frequency components (edges, stripes, corners), there will be a number of points in the frequency domain at high-frequency values.

The equation for the Fourier transform, X, of a signal x, is given by the complex integral below:

$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-i\omega t} \, dt$$

Low Pass Filter

A low-pass filter, also called a "blurring" or "smoothing" filter, averages out rapid changes in intensity. The simplest low-pass filter just calculates the average of a pixel and all of its eight immediate neighbors. The result replaces the original value of the pixel. The process is repeated for every pixel in the image.

This low-pass filtered image looks a lot blurrier. But why would you want a blurrier image? Often images can be noisy – no matter how good the camera is, it always adds an amount of ”snow” into the image. The statistical nature of light itself also contributes noise into the image.

Noise always changes rapidly from pixel to pixel because each pixel generates its own independent noise. The image from the telescope isn't "uncorrelated" in this fashion because real images are spread over many pixels. So the low-pass filter affects the noise more than it does the image. By suppressing the noise, gradual changes can be seen that were invisible before. Therefore a low-pass filter can sometimes be used to bring out faint details that were smothered by noise.

MaxIm DL allows you to selectively apply a low-pass filter to a certain brightness range in the image. This allows you to selectively smooth the image background, while leaving the bright areas untouched. This is an excellent compromise because the fainter objects in the background are the noisiest, and it does not degrade the sharpness of bright foreground objects.

High Pass Filter:

A high-pass filter can be used to make an image appear sharper. These filters emphasize fine details in the image – exactly the opposite of the low-pass filter. High-pass filtering works in exactly the same way as low-pass filtering; it just uses a different convolution kernel. In the example below, notice the minus signs for the adjacent pixels. If there is no change in intensity, nothing happens. But if one pixel is brighter than its immediate neighbors, it gets boosted.

Unfortunately, while low-pass filtering smooths out noise, high-pass filtering does just the opposite: it amplifies noise. You can get away with this if the original image is not too noisy; otherwise the noise will overwhelm the image. MaxIm DL includes a very useful "range-restricted filter" option; you can high-pass filter only the brightest parts of the image, where the signal-to-noise ratio is highest.

High-pass filtering can also cause small, faint details to be greatly exaggerated. An over-processed image will look grainy and unnatural, and point sources will have dark donuts around them. So while high-pass filtering can often improve an image by sharpening detail, overdoing it can actually degrade the image quality significantly.

Conclusion:

Successful completion of these experiments highlights the importance of image processing techniques in machine vision applications. The comprehensive understanding of color space conversion, Fourier transformation, high-pass filtering, and low-pass filtering equips practitioners with powerful tools to tackle complex image analysis tasks and contribute to advancements in various industries and research domains.