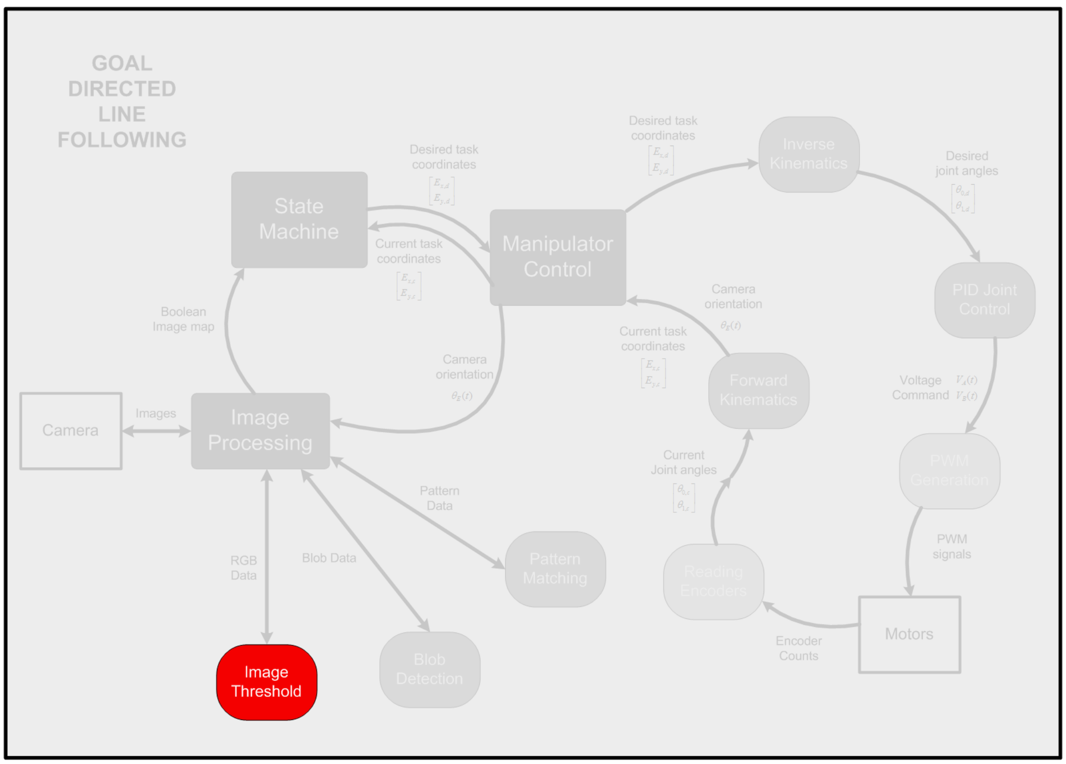
Image Threshold

Topics Covered

- Image Thresholding in LabVIEW™
- Image Thresholding for different lighting conditions

Prerequisites

- The QNET Mechatronic Systems is set up according to the Quick Start Guide.



1 Background

1.1 Image Representation

Images represent a snapshot state of a dynamic world. When using a single image, interpreting the information from it can prove difficult without the knowledge of how that information changes. For example, looking at successively snapped images of a moving ball, a computer can correlate the change in specific pixels colours to that of a moving object, therefore identifying the ball. However, it cannot use a single still image to directly identify the ball. In such cases, image segmentation is often the first step. This class of techniques involves isolating information about objects in an image based on their properties that are static and known.

Image thresholding is one such technique of image segmentation, which reduces an image to a binary format, that is, all information in the image is reduced to two categories - foreground and background. Consider the example above - knowing that the ball is red, the computer can correlate any cluster of red particles in an image to a 'ball' (foreground), and all other information as 'not a ball' (background). Image thresholding is used as the entry step towards multitudes of other algorithms. It has a wide variety of applications, from improving readability of historical manuscripts, and medical imaging, to augmented reality. Before exploring the method itself, an understanding of images is required. Note that images are a 2D projection of our 3D world with various properties, which can be represented as the following function,

$$f(x,y) = W(\rho, \phi, \alpha, V, M, L, A, \epsilon) \tag{1.1}$$

where $f(x,y)$ is the captured 2-D image with x and y referring to pixel row and column, W is a function of the geometry in spherical coordinates ρ, ϕ and α (as an example) of the objects present in the viewpoint V, M represents the material, L represents the lighting conditions, A represents the atmosphere and ϵ represents errors. One simple representation for $f(x,y)$ can be a 2D array carrying pixel values as binary numbers. Using 8-bit numbers is referred to as a Gray-scale image (which allows a range of values from 0 to 255). Using 4 sets of 8-bit numbers per pixel for Red, Green, Blue and Gray, can yield a 32-bit colour image, etc.

1.2 Image Thresholding

Thresholding is an operation that is often used to isolate specific colours or brightness levels in an image. In general, a spatial domain process like thresholding is denoted by the following expression:

$$h(x,y) = T\big(f(x,y)\big), \tag{1.2}$$

where $f(x,y)$ is the input image, $h(x,y)$ is the processed image, and T is the thresholding operation. The function T can be implemented on the image pixels in one of the following ways:

- Binary thresholding:
  $$T\big(f(x,y)\big) = \begin{cases} 255 & \text{if } R_l \le f(x,y) \le R_u \\ 0 & \text{otherwise} \end{cases}$$
- Binary thresholding inverted:
  $$T\big(f(x,y)\big) = \begin{cases} 0 & \text{if } R_l \le f(x,y) \le R_u \\ 255 & \text{otherwise} \end{cases}$$
- Truncate to a value
  $$T\big(f(x,y)\big) = \begin{cases} trunc & \text{if } R_l \le f(x,y) \le R_u \\ f(x,y) & \text{otherwise} \end{cases}$$

- Threshold to zero:
$$T\big(f(x,y)\big) = \begin{cases} f(x,y) & \text{if } R_l \leq f(x,y) \leq R_u \\ 0 & \text{otherwise} \end{cases}$$
- Threshold to zero, inverted:
$$T\big(f(x,y)\big) = \begin{cases} 0 & \text{if } R_l \leq f(x,y) \leq R_u \\ f(x,y) & \text{otherwise} \end{cases}$$

where the threshold range is defined with $[R_l, R_u]$ and $trunc$ denotes an arbitrary level of truncation. The above equations can be used for Gray-scale image thresholding directly. For colour image thresholding, similar functions can be applied to each channel of the image. For example, binary thresholding for RGB images can be written as:

$$T\big(f(x,y)\big) = \begin{cases} f(x,y) & \text{if range-condition } = true \\ 0 & \text{otherwise} \end{cases} \tag{1.3}$$

in which range-condition can be written as the logical AND of three conditions, $R_{r,l} \leq f(x,y) \leq R_{r,u}$, $R_{g,l} \leq f_g(x,y) \leq R_{g,u}$ and $R_{b,l} \leq f_b(x,y) \leq R_{b,u}$ where r, g and b subscripts denote the red, green and blue channels, respectively.

2 In-Lab Exercises

In this exercise, Binary Thresholding is used on Gray-scale 8-bit images $f(x, y)$ captured by the QNET Mechatronic Systems camera. If the pixel value falls between the lower and upper ranges, it is set to 255 (white), otherwise it is set to 0 (black).

1. Open `Mechatronic Systems.lvproj`, and under `Quanser ELVIS RIO | Subsystems`, open `Image Threshold.vi`. Run the VI. Once the Calibration bar is full, move the manipulator manually and confirm that the camera is capturing live images. Keep the Lower Threshold Range slider at 0 and gradually raise the Upper Threshold Range slider to 60, then 130 and then 150. Use the colour frequency histogram for reasoning. What do you observe and why? Attach the original and processed images.
2. Based on your analysis in the previous question, what upper threshold range is recommended for optimal road information analysis? Note that final answers may vary based on your lighting conditions.
3. Place your palm around and below the camera to prevent some light from illuminating the silk board. With the *Upper threshold range* still set the optimal value from the previous answer, does the processed image still capture road information clearly? Attach the original image, histogram and processed image, without and with your hand.
4. With your hand still blocking some of the light, what Upper threshold range would you suggest to use based on information from the color frequency histogram? Show the processed image with this new value. Note that final answers may vary based on your lighting conditions.

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