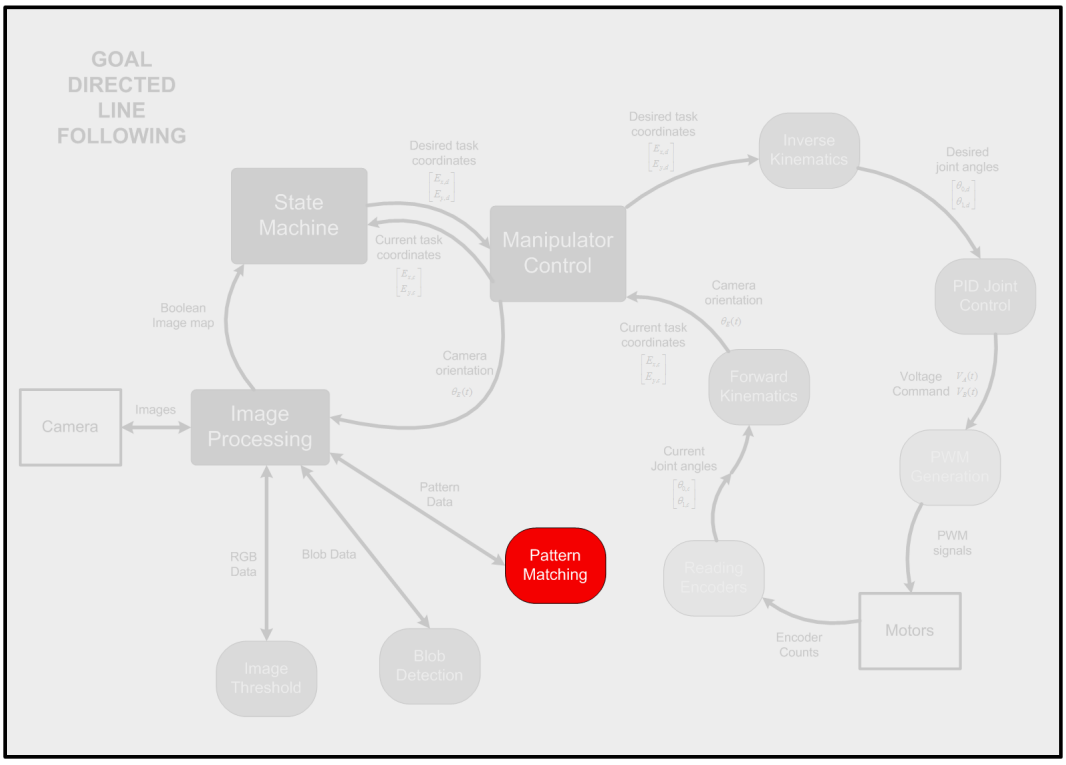
Pattern Matching

Topics Covered

- Pattern Matching in LabVIEW™
- Using Pattern matching to extract road information

Prerequisites

- The QNET Mechatronic Systemshas been set up according to the Quick Start Guide.
- Image Threshold laboratory experiment.
- Blob Detection laboratory experiment.



1 Background

1.1 Pattern Matching

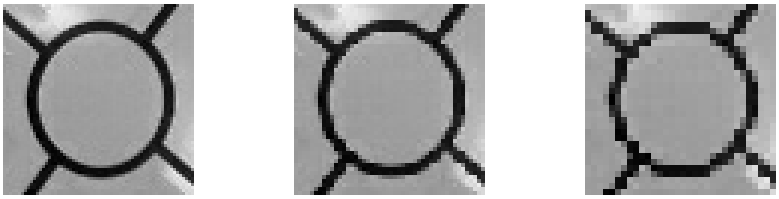
Pattern matching is a branch of pattern recognition, in which, the pattern or template is provided. When the computer is looking for an object in an image with intricate details or key features that blob detection alone cannot uniquely identify, pattern matching can be used. For example, if blob detection is used to differentiate between a filled pentagon and a solid circle, the results may provide similar areas, and boundary types. Pattern matching can uniquely identify this difference based on a template. Matches can be assigned scores that depend on the level of accuracy in comparison to the template. This can be represented by the following function,

$$\big(X, Y, \psi, \eta, \Gamma, N\big) = P\big(f(x,y), h(x,y)\big), \tag{1.1}$$

where $f(x,y)$ is the 2-D image within which the pattern is to be found (source image), $h(x,y)$ is the 2-D template image that holds the pattern that is to be found (template image), x and y refer to the row and column pixel index, P is the pattern matching algorithm/operation, X and Y refer to the pixel location of the centre of the matches, ψ refers to the angle the matches are rotated by with respect to the template, η is the scaling ratio between the matches and template, Γ is the match scores, and N is the number of matches found in f(x,y). Limitations can be placed on these properties if the user has additional information regarding the required match, for example, only matches between ± 10 ° of the template can be selected. Various pattern matching algorithms can be used for the operation P, such as, Low Discrepancy Sampling, Gradient Pyramids, Gray-scale Value Pyramids, etc.

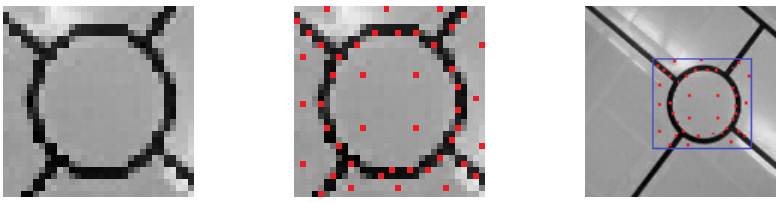
1.2 Low Discrepency Sampling

More often than not, the template can have large amounts of redundant data, which is similar. For example, consider the template in Figure 1.1a. This template has large chunks of Gray blocks which are similar and are not necessarily useful in matching the road pattern. Images b, and c in Figure 1.1 are smaller scale versions which convey the same basic information but at a much lower resolution.



(a) 64px by 64px (b) 48px by 48px (c) 32px by 32px

Figure 1.1: Lower resolution Templates



(a) Template image (b) 46 points selected (c) Source image

Figure 1.2: Template image found

In a similar fashion, Low discrepancy sampling selects a small subset of pixels from the template that provide key information, and then looks for similar arrangements of these pixels in the source image, as shown in Figure 1.2. The arrangement of 46 pixels selected from the template in Figure 1.2a can be seen in Figure 1.2b. An arrangement of pixels is found on a 1.9 magnification in Figure 1.2c, with no rotation and a score of 869 (out of 1000) based on the number of pixels matched (40 out of 46).

The pixels selected in the template can be randomly selected from a larger group, or through techniques such as image thresholding, edge detection and blob analysis, which rely on differences in colour values between adjacently placed pixels. The main advantages of using Low Discrepancy sampling includes the fast pattern matching speed.

2 In-Lab Exercises

In this exercise, Pattern matching is used on a Gray-scale 8-bit images $f(x, y)$ captured by the QNET Mechatronic Systems camera. The template images are snapshots taken from the QNET Mechatronic Systems camera as well, and contain images related to the Star, Plus, X, North, traffic lights and a branch intersection, all located on the QNET Mechatronic Systems.

1. Open `Mech Systems ELRIO.lvproj`, and under `Quanser ELVIS RIO | Subsystems`, open `Pattern Matching.vi`. Run the VI. Once the Calibration bar is full, move the manipulator manually and confirm that the camera is capturing live images. Select Low Discrepancy Sampling as the Algorithm and set the Number of Matches Requested to 1. Set the Minimum Match Score to 400 (40% accuracy), and set the Start and End angles to 0 and 10° respectively. Select the Star pattern. Move the manipulator over the Star pattern on the QNET Mechatronic Systems. Does the Matches information and matching behaviour make sense?
2. Given that the algorithm incorrectly identifies the star pattern and hops around to multiple results, how can this issue be rectified? Make the corresponding modification in the settings and show your result.
3. Select the Plus pattern and repeat the search with a Minimum Match Score of 400. What do you observe? Improve the accuracy with a different score, based on your results from the previous question.
4. Select the Branch pattern and keep the Minimum Match Score at 900. Does the algorithm find any incorrect matches? Why or why not?
5. Repeat the search algorithm with the Bigger Branch pattern, and comment on the results.
6. Consider the case below where the straight road pattern was used with a Minimum Match Score set to 900. Assuming the manipulator's end-effector is located at the centre of the image (point O at [64 px, 64 px]^T in Figure 2.1), how can you use the match results to get the vector displacement towards the edge of the road (point Q in Figure 2.1)? Note that the pattern matching information provides the centre of the pattern P at [30 px, 77 px]^T, it's rotation as 127°, the road in the Bigger Branch pattern is 72 pixels long, and that the centimetre to pixel conversion is 0.0275 cm/px. Calculate the displacement $\vec{OQ}$. Is the displacement vector consistent with the coordinate frame of the QNET Mechatronic Systems?

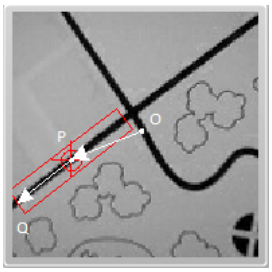


Figure 2.1: Getting vector displacement from the match information

7. Based on your understanding from this lab, how does the information carried by the template image affect the accuracy of pattern matching? Are there any drawbacks to using pattern matching for localization and mapping?

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