Object Detection & Template Matching in Subaquatic Environment

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ABSTRACT

This paper focuses on the implementation of Computer Vision algorithms to accomplish a sub-set of tasks as required by the AUVSI's International Autonomous Underwater Vehicle Competition [1]. These algorithms are to be used by SubjuGator, UF-MIL's entry to the said competition.

Keywords

Object, Detection, Segmentation, Template, Matching.

1. INTRODUCTION

The algorithms are roughly divided into two parts: 1. Object Detection, 2. Template Matching. Use of Morphological Operations has been explored for segmentation. For dim images a technique which calculates ratio between image channels is used. In the case of Template Matching, to incorporate the features of Rotation and Scaling Invariance, the Ring Projection Transform technique [2] has been implemented. Significant increase in the robustness of the techniques is observed when the both are used in tandem.

2. OBJECT DETECTION

2.1 Morphological Operations [3]

2.1.1 Dilation

Dilation adds to the boundaries of objects, in terms of pixel thickness. While performing dilation the maximum value from neighborhood of the pixel in input image forms the value of the pixel in the output image.

2.1.2 Erosion

Erosion, quite truly, erodes the pixel boundaries of images. For erosion, the minimum value from the neighborhood of the pixel in the input image forms the value of the pixel in the output image.

2.1.3 Structural Element

The neighborhood is usually defined by a structural element like a diamond, an ellipse or a rectangle, the choice being largely dependent on the application. In the current application a circular structural element is used.

2.1.4 Results using Morphological Operations

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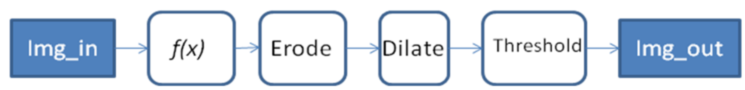


$$f(x) = \{2*R - (B+G) + 512\}/512$$

Figure 1. a. Segmentation Algorithm Flow

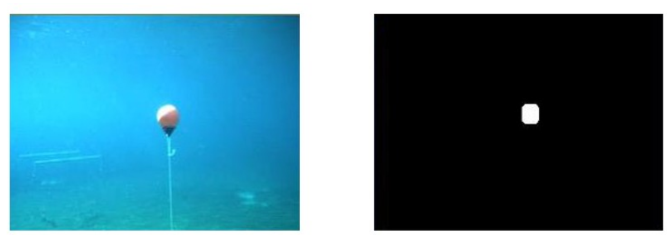


Figure 1. b. Segmentation for Buoy

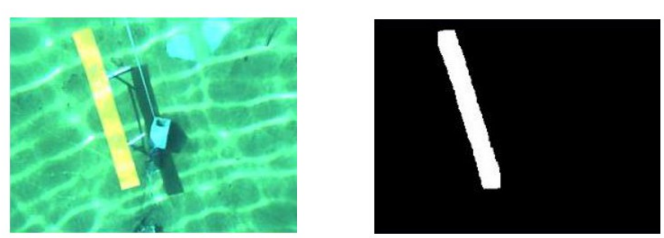


Figure 1. c. Segmentation for Pipe

2.2 Ratio of Channels

Under low lighting conditions (Figure 2. a.) esp. for the given conditions, i.e. under water, the segments of interest in the image are barely visible, even to the human eye. Under such conditions the fact that the segments belong to particular color can be used to greatly enhance the segments (Figure 2. b.)

Img_out(i,j)= Threshold({float(Img_in.r(i,j))/Img_in.b(i,j)},0.39)

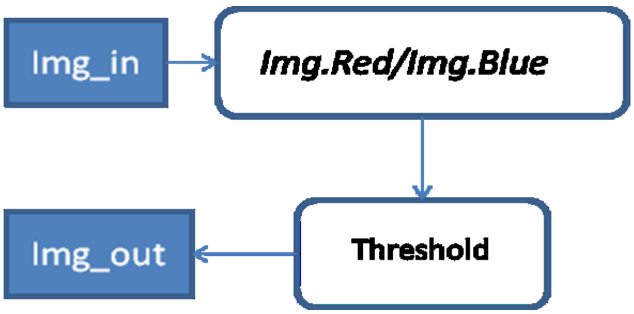


Figure 2. a. Segmentation Technique for Low Lighting Conditions

3. TEMPLATE MATCHING

3.1 General Rotation and Scaling Invariant Template Matching [2]

The implemented algorithm involves the calculation of the Ring Projection Transform (RPT) for varying scales of the template. The ring projection transform entails calculating the average intensities on circles of varying radii, all of which are concentric on the center of the template. Thus a 2-D template image yields a 1-D Ring Projection Vector (RPV). It is because of this projection technique that the algorithm is invariant to rotation. A set of projection vectors, calculated in the same way, is moved along the scene image and is correlated with the RPV at every point. Analysis of the degree of correlation between these vectors results in a template match.

To be able to match the template over different scales, the RPT process is performed over varying scales of the template, of which the original template is just one member. For cases in which the scaled template is smaller than the original template, the resulting RPV is padded with zeros. For cases where the scaled template is larger than the original template, the RPT process is stopped when the RPV length is equal to the RPV length of the un-scaled template. Thus the resulting RPV's for all the templates are equal in length [4].

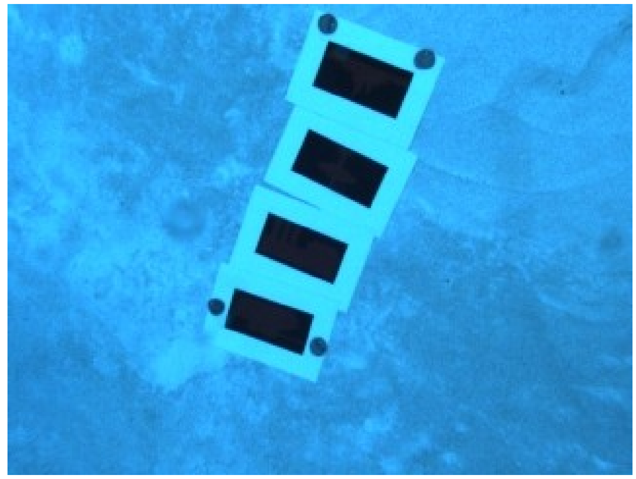


Figure 2. b. Image under Low Lighting Conditions

Figure 2. c. Segments Hidden inside *Figure 2. a.*

The following equations are to be solved for RPT template matching:

$$\overrightarrow{P_{tp}} = \frac{\overline{P_{t0}}\omega_0 + \overline{P_{t1}}\omega_1 + \cdots + \overline{P_{tN}}\omega_N}{\left|\overline{P_{t0}}\omega_0 + \overline{P_{t1}}\omega_1 + \cdots + \overline{P_{tN}}\omega_N\right|}, 0 \le \omega_i \le 1, \sum \vec{\omega} = 1 \cdots (1)$$

$$\vec{\omega} = \frac{H^{-1}\vec{G}}{\left(\vec{n} \cdot H^{-1}\vec{G}\right)} \cdots (2)$$

$$\vec{\omega} \triangleq \begin{bmatrix} \omega_0 \\ \vdots \\ \omega_N \end{bmatrix} \cdots (3)$$

$$H \triangleq \begin{bmatrix} \langle \vec{P}_{t0}, \vec{P}_{t0} \rangle & \cdots & \langle \vec{P}_{t0}, \vec{P}_{tN} \rangle \\ \vdots & \ddots & \vdots \\ \langle \vec{P}_{tN}, \vec{P}_{t0} \rangle & \cdots & \langle \vec{P}_{tN}, \vec{P}_{tN} \rangle \end{bmatrix} \cdots (4)$$

$$\vec{G} \triangleq \begin{bmatrix} \langle \vec{P}_S, \vec{P}_{t0} \rangle \\ \vdots \\ \langle \vec{P}_S, \vec{P}_{tN} \rangle \end{bmatrix} \cdots (5)$$

$$\vec{n} \triangleq \begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix} \cdots (6)$$

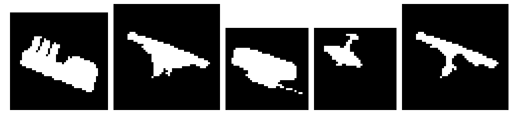
$\langle \vec{P}_A, \vec{P}_B \rangle$ is equivalent to normalized correlation (NC) between two arbitrary RPVs namely A and B. While scanning through the scene image, the objective is to maximize the NC $\langle \vec{P}_S, \vec{P}_{tP} \rangle$ at every point such that all the above 6 equations are satisfied. The points where such NC values are above the threshold can be considered to be template matches.

Figure 3. a. Arbitrary Scene Image

Figure 3. b. Template Marked in the scene image (to the left of the rainbow)

3.2 Template Matching for the given Subaquatic Conditions

The technique used in 2.2 is implemented to find the template images (Figure 4).



(a) (b) (c) (d) (e)

Figure 4. Template *(a) factory, (b)destroyer, (c)tank, (d)plane and (e)modified destroyer*

The figure 5 demonstrates three cases where the template matching is implemented on the scene. Figure 5. c. is an error in marking and the "destroyer" is wrongly marked as "plane". Figure 5. a. has marked a point reasonably close to the intended target,

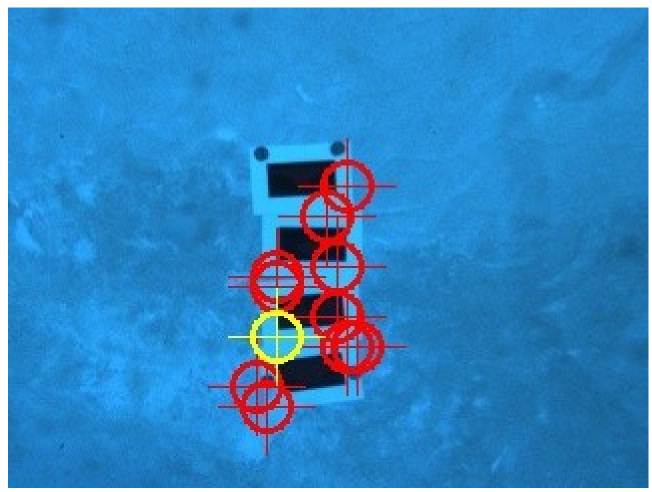


Figure 5. a. Template matching with "tank" as the template

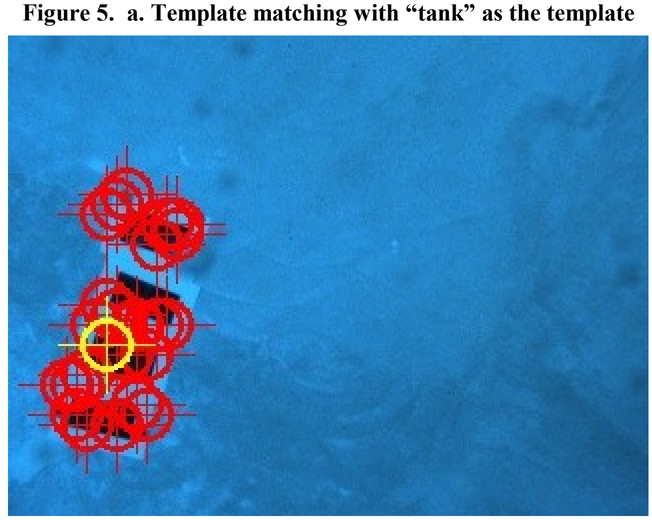


Figure 5. b. Template matching with "factory" as the template

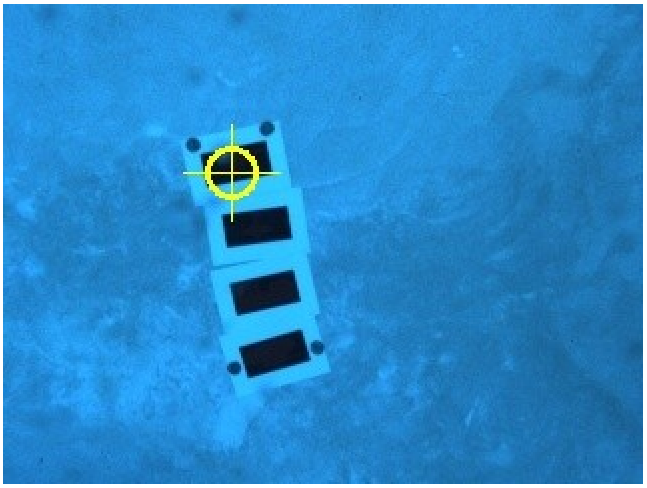


Figure 5. c. Template matching with "plane" as the template; the destroyer is erroneously marked as plane.

i.e. the tank. Figure 5. b. is a near perfect hit where the factory is the target (refer figure 2. b. for relative locations). Figure 4. d. though inaccurate as that of the destroyer, separates it from the tank template and improves the accuracy of template matching.

4. CONCLUSIONS

In underwater environments object detection can be improved by focusing on the color channels of interest. The RPT process is unsuitable for differentiating between images like ("2", "Z" and "S") or ("M","W"). The reason behind is that the given groups generate very similar RPVs throughout their respective groups. The inherent inadequacies of the RPT process for template matching can be overcome by choosing, designing and preprocessing suitable templates.

5. ACKNOWLEDGMENTS

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