Journal of Robotics, Networking and Artificial Life
Vol. 5(4); March (2019), *pp.* 223–227
DOI: https://doi.org/10.2991/jrnal.k.190220.002; ISSN 2405-9021 print; 2352-6386 online
https://www.atlantis-press.com/journals/jrnal

Research Article

Development of Automation Recognition of Hazmat Marking Chart for Rescue Robot

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ARTICLE INFO

Article History
Received 11 October 2018
Accepted 19 December 2018

Keywords
Hazmat marking chart
SURF
FLANN
rescue robot

ABSTRACT

A long history of first place awards in World RoboCup Rescue Robot competitions is Invigorating Robot Activity Project (iRAP) such as iRAP_PRO, iRAP_FURIOUS, iRAP_JUNIOR, and iRAP_ROBOT. In this paper, we would like to introduce and explain an autonomous system of our rescue robots for detection and recognition of hazardous material (Hazmat) marking charts. All Hazmat tags are considered and computed by using speeded-up robust feature combined with fast library for approximate nearest neighbors to match with the templates. Finally, the paper presents experimental results based on real situations to confirm an effect of the pattern recognition of robotics.

1. INTRODUCTION

Invigorating Robot Activity Project (iRAP) is the robotics club of students from King Mongkut's University of Technology North Bangkok, Thailand. Every year, we participate in the World RoboCup Rescue Robot competitions, and our teams have won first place many times in the competitions [1]. Our rescue robot can be divided into three major parts such as the mechanical robot part, the electrical system part, and the software system part. The unique point of the iRAP_ROBOT is the human–robot interface (the operator console), which can show and present extensive sensor values and visual data (CO_2 sensor, visual temperature sensor, laser-scanner, IMU sensor and four cameras) in real time as shown in Figure 1. Moreover, our rescue robot is designed based on proficiency by the agility and performance tests.

2. STRUCTURE OF iRAP_ROBOT

The structure of the iRAP rescue robot is an original platform for the rescue robot which has two pairs of flippers (in the front and in the rear) as shown in Figure 2. In addition, the 6-DOF robotic arm (one prismatic joint and five revolute joints) is set up on a body of the robot, to search and observe the victim and situation in the surrounding area. The multi-sensors are installed in the end-effector of robotic arm, and also, the camera on the robotic arm is used for recognizing the Hazmat chart autonomously.

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3. AUTOMATIC RECOGNITION OF HAZMAT CHART

The proposed paper that presents the Speeded-up Robust Feature (SURF) method [2] for extraction the information from the image and then using the Fast Library for Approximate Nearest Neighbors (FLANN) model [3–5], which is used to match the input image with Hazmat chart templates. And the system uses blob detection [6] to mark the position of Hazmat chart. The overview system can be divided into two phases: the initialization phase (Figure 3) and the real-time processing phase.

3.1. Initialization Phase

3.1.1. Load all template images

The first part of initialization phase is to input all the Hazmat chart templates. There are 12 templates for training the proposed methods as displayed in Figure 4.

3.1.2. Pre-processing image

In the pre-processing image, there is a common task to improve or adjust the feature of image (scale, color, edge, area etc.).

3.1.3. Feature extraction

The SURF algorithm is applied to the feature extraction. It consists of detector (Hessian matrix), as expressed and descriptor

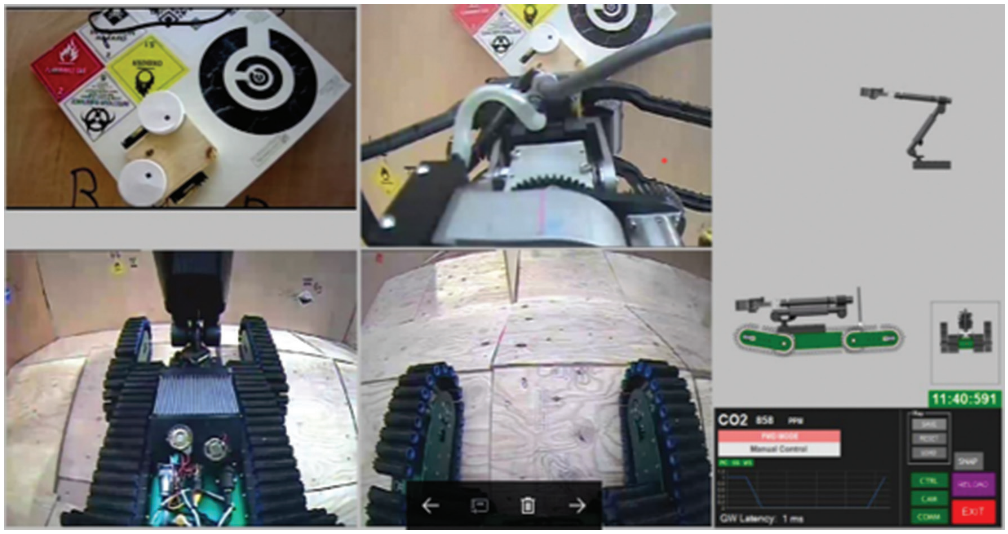

Figure 1 | Operator console of iRAP_ROBOT.

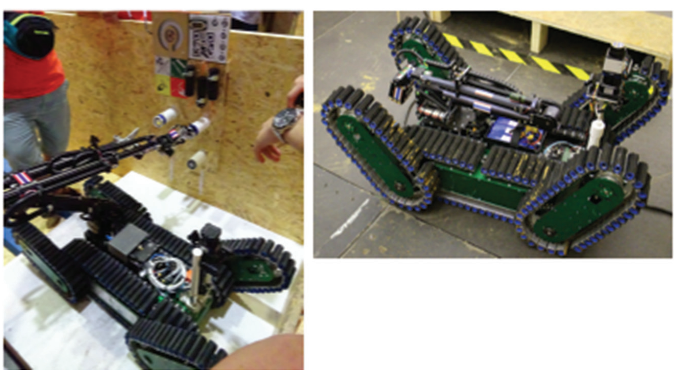

Figure 2 | iRAP rescue robot.

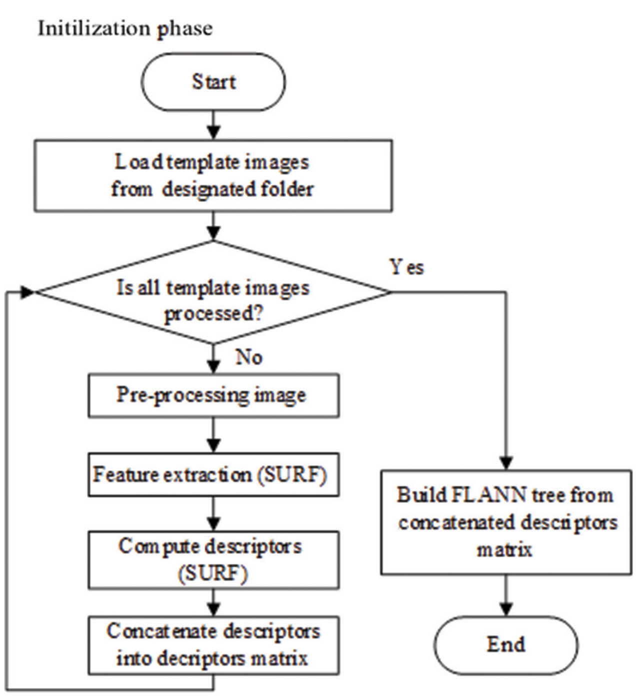

Figure 3 | Initialization phase of the proposed method.

Figure 4 | Hazmat chart templates.

schemes (Haar wavelet). The determinant of a Hessian matrix in Equation (1) shows the expression of the local change around the area, where $H(x, \sigma)$ is the hessian matrix, as illustrated in Equation (2), and $D_{xx}(x, \sigma)$, $D_{xy}(x, \sigma)$ in Equations (3) and (4) are the convolution of the integral image and the second derivative of the Gaussian function.

$$\det(H_{\text{approx}}) = D_{xx}D_{yy} - (wD_{xy})^2 d \tag{1}$$

$$H(x,\sigma) = \begin{bmatrix} D_{xx}(x,\sigma) & D_{xy}(x,\sigma) \\ D_{xy}(x,\sigma) & D_{yy}(x,\sigma) \end{bmatrix} \tag{2}$$

$$D_{xx}(x,\sigma) = I(x) * \frac{\partial^2}{\partial x^2} g(\sigma) \tag{3}$$

$$D_{xy}(x,\sigma) = I(x) * \frac{\partial^2}{\partial xy} g(\sigma) \tag{4}$$

After having create the response map, the next step is to consider a non-maximum suppression based on the determents of the Hessian matrix that is the objective of the SURF detection.

3.1.4. Compute descriptors

At each interest point, we have to indicate the unique description of a feature that do not depend on the size and rotation. The SURF descriptor is based on the Haar wavelet model that can be calculated efficiently with integral images. The wavelets response in the x- and y- direction is defined as dx and dy respectively as shown in Figure 5. For each sub-area of a vector, descriptors are calculated based on Equation (5).

$$v_{\text{sub}} = \left[\sum dx, \sum dy, \sum |dx|, \sum |dy|\right] \tag{5}$$

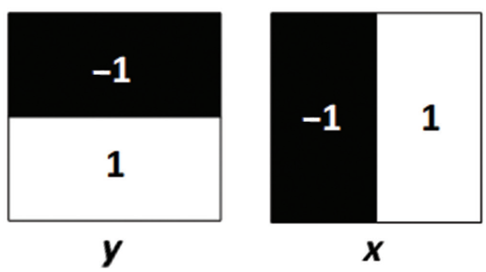

Figure 5 | The wavelets response. Black and white areas show the weight −1 and 1 for the Haar kernels.

3.1.5. Concatenate descriptors

In this sub-process, it is created by the new platform of descriptors to the sample feature. Then, we have 12 sample feature descriptors to match with the input image.

3.2. Real-time Processing Phase

The real-time processing phase (Figure 6) is similar to an initialization phase. First, the acquired image is input into the main process. The SURF method is used to extract the interest points and compute the descriptors. And then, the descriptors of the input image are compared with all sample images. The similarity score of the keypoint is calculated in each class, Finally, the input image is specified in the winner class, which is the maximum similarity score. Then, the position of the Hazmat image is in the frame that will be considered to calculate the centroid of an interest area.

4. EXPERIMENTAL RESULTS

The experimental results were verified with the Visual Studio C# program and an open source library such as Emgu CV library.

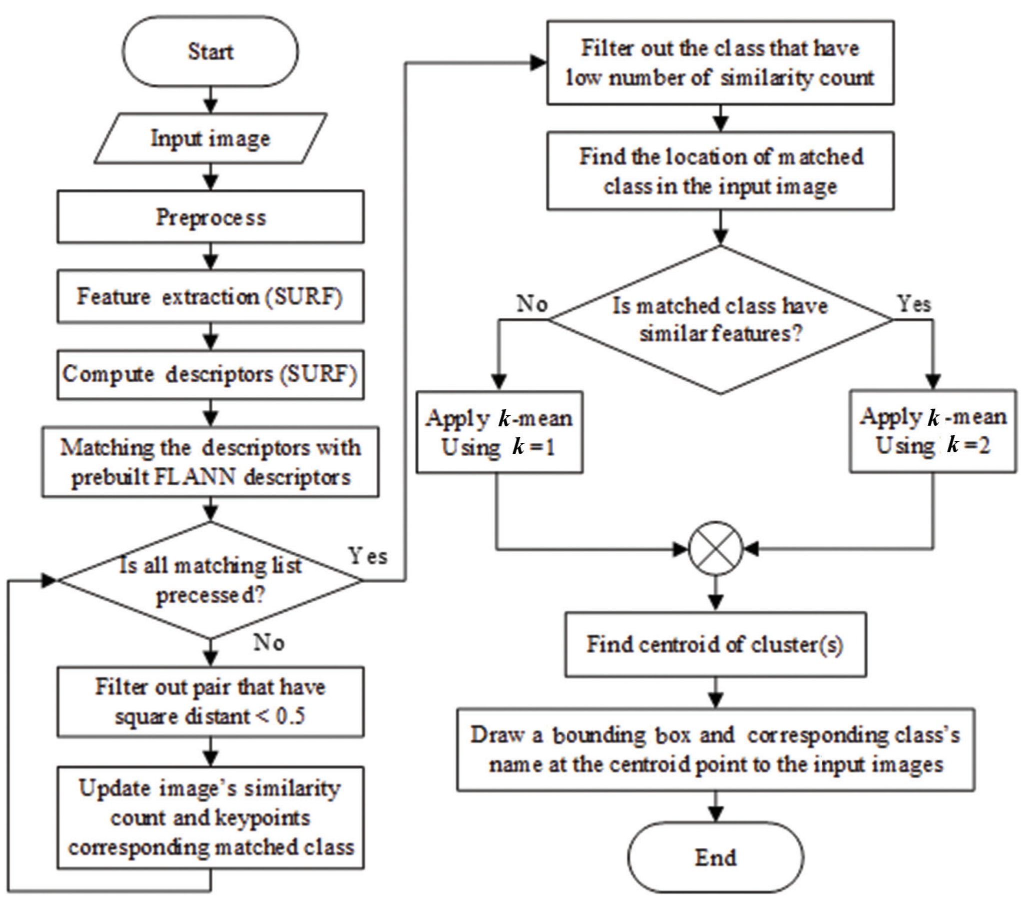

Figure 6 | Real-time processing phase.

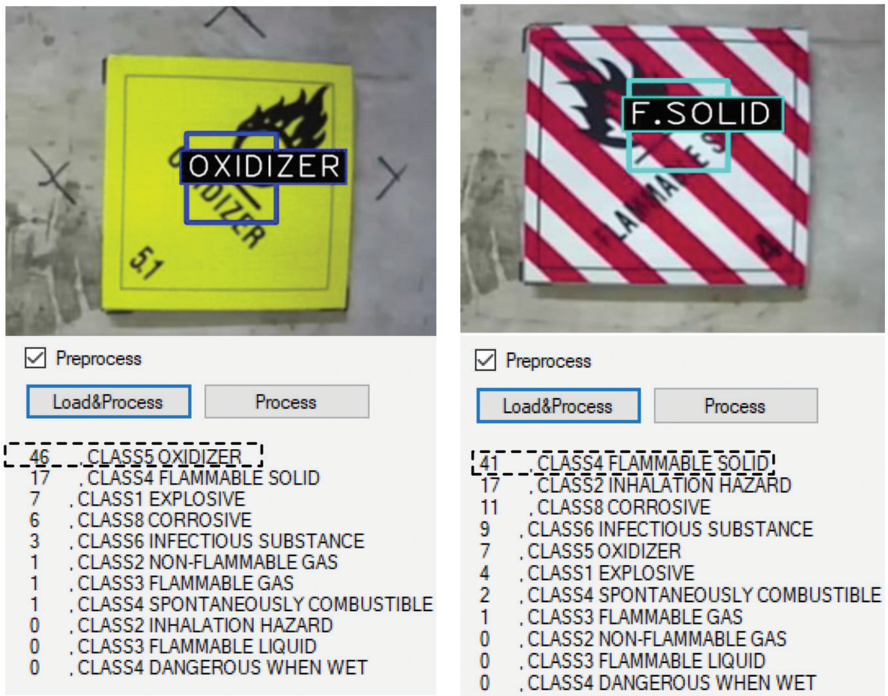

Figure 7 | One Hazmat chart matching. (a) Oxidizer Hazmat chart. (b) Flammable solid Hazmat chart.

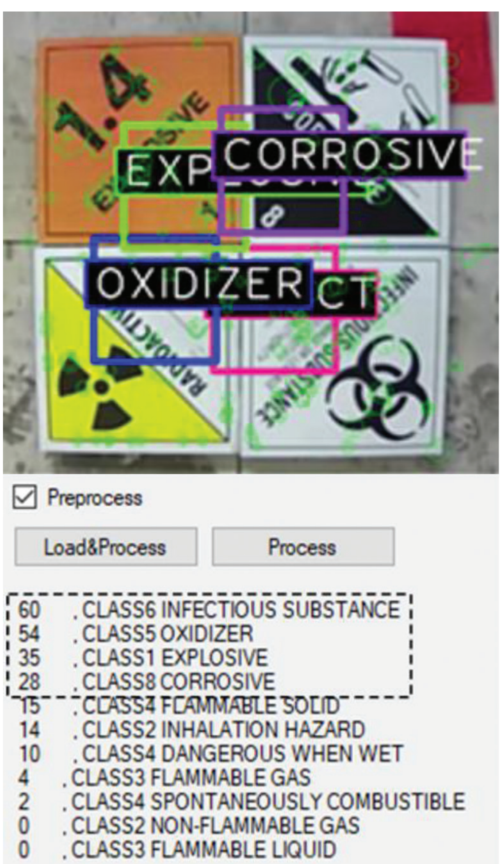

Figure 8 | Four Hazmat charts matching.

4.1. Verification I

In this case there is only one Hazmat image in the frame, the results of the proposed method can be used in recognition and detection autonomously, it did not depend on the size of input image and rotation. In Figure 7a and 7b, the system that will select highest similarity score as the answer.

4.2. Verification II

Besides, we had more testing of the proposed method by adding four Hazmat charts as the input image to verify the uncertain image group. In Figure 8, the experimental results show four maximum similarity scores such as “INFECTIOUS SUBSTANCE (Class6)”, “OXIDIZER (Class5), “EXPLOSIVE (Class1)”, and “CORROSIVE (Class8)”, which were matched with the training images. The results that confirm the proposed method can classify and identify the Hazmat chart accurately and correctly. Moreover, our proposed method that could draw the frames and mark the position of each Hazmat chart is based on their density features.

5. CONCLUSION

This paper presents the development of the automatic recognition of a Hazmat marking chart for rescue robots. The results that affirm the proposed method can be used in detection and recognition in the real situation. In the future work, we will improve not only the speed of the recognition system but also the accuracy of method using deep learning method.

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