

# COGNITION SYSTEM OF BOLT HOLE USING TEMPLATE MATCHING

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**ABSTRACT:** In the construction field, the bolting robot provides convenience and reduces a process time of assembling steel frames. When assembling steel frames, the bolting robot finds a bolt hole with the help of camera. If the light conditions are either too bright or too dark, however, it is hard to find a bolt hole in the input image because the contrast between bolt hole and background is vague. In order to improve detection accuracy in such environment, this paper proposes the image processing algorithm using template matching (TM). First, the input image is converted from RGB to YCbCr in order to reduce influence of shadow. Then we separate Y channel of image in darkness or extract edges from Cb and Cr channel of image in brightness. Template image is created with the radius which can be calculated with the distance to a steel frame. We used TM to create the normalized cross correlation (NCC) image which shows correlation between processed image and template. Finally, bolt holes are extracted from the high-correlation part of NCC image. Experimental results show that the proposed method is robust to detect bolt holes under various illumination conditions.

**Keywords:** Construction Automation, Robot, Bolt Hole Detection, Image Processing, Template Matching

## 1. INTRODUCTION

The usage of robots is increasing in the area of construction automation. The bolting robot system is being developed in order to be used in the construction field. It finds bolt holes with the help of camera. So the image processing is key technique for the bolting robot to find bolt holes.

Circular Hough transform is generally used to extract circular object [1]. Since the bolt holes are circular object, CHT is used to find them [2]. CHT needs edge detected image to extract bolt holes. But if the edges are not clear in darkness or background of hole is similar to frame [3], it is difficult to find bolt holes by using CHT.

In order to use robot under various illumination conditions and operate unmanned, we propose a robust method that uses template matching to detect bolt holes in such environment. The format of image used for TM is YCbCr which shows well contrast between bolt hole and the others.

This paper is organized as follows: the bolting robot is introduced in Section 2 and we will deal with TM in Section 3. After that, we will propose a sequence of

image processing to detect bolt holes in Section 4. Then experimental results are given in Section 5. Finally, in Section 6, we present conclusions.

## 2. BOLTING ROBOT

### 2.1 Organization of bolting robot

The bolting robot consists of video camera, laser rangefinder, gantry robot and a bolting tool. Fig. 1 represents a bolting robot system. LED light is equipped in order to reduce an effect of shadow when using CHT.

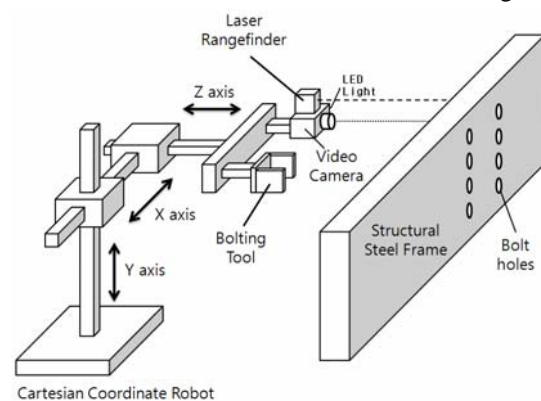


Fig. 1 Organization of Bolting Robot

## 2.2 Determining the radius of a bolt hole

The bolting robot has a laser range-finder on the camera in order to measure the distance to a steel frame. Denoted  $R$  in Fig. 2 is the radius of a desired bolt hole in input image. The measurement of  $R$  is carried out with the apparatus described in Fig. 2.

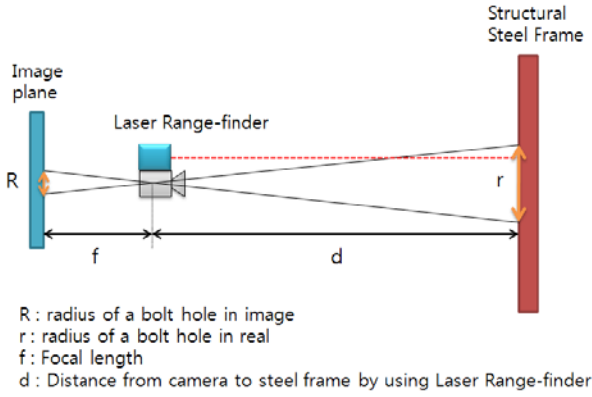


Fig. 2 Installation to determine a bolt-hole radius

Let  $f$ ,  $d$ , and  $r$  denote focal length  $f$ , distance  $d$  from camera center to frame and radius  $r$  of hole in the steel frame, respectively. We can derive a proportional Eq. (1) with given parameters  $f$ ,  $d$ , and  $r$ .  $R$  is used to create a template image.

$$R = r \cdot \frac{f}{d} \quad (1)$$

## 3. TEMPLATE MATCHING (TM)

TM is one of pattern recognition techniques to find a desired part which is similar to template. For the similarity measure, the sum of absolute difference (SAD) and the sum of squared differences (SSD) are widely used to various applications [4][5]. SAD and SSD are defined as follows:

$$SAD(i, j) = \sum_{x=1}^m \sum_{y=1}^n |T(x, y) - I(x + i, y + j)|, \quad (2)$$

$$SSD(i, j) = \sum_{x=1}^m \sum_{y=1}^n (T(x, y) - I(x + i, y + j))^2. \quad (3)$$

In addition to them, the normalized cross correlation (NCC) measure is also popular similarity measure. NCC is more robust than SAD and SSD under illumination changes [4][6]. Especially, the FFT-based method

calculates the cross correlation in the frequency domain [4]. NCC is defined as follows:

$$NCC(x, y) = \frac{\sum_{i=1}^M \sum_{j=1}^N T(i, j) \cdot I(x+i, y+j)}{\sqrt{\sum_{i=1}^M \sum_{j=1}^N I(x+i, y+j)^2} \cdot \sqrt{\sum_{i=1}^M \sum_{j=1}^N T(i, j)^2}} \quad (4)$$

## 4. SEQUENCE OF IMAGE PROCESSING

In this section, the image processing is introduced. Fig. 3 is block diagram of the proposed image processing.

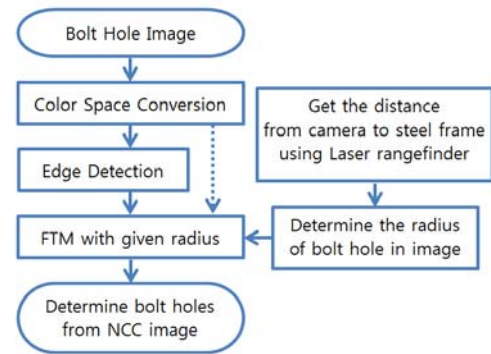


Fig. 3 Block Diagram of Bolt Hole Detection

### 4.1 Color space conversion

YCbCr color model consists of three channels: luminance (Y) and chrominance (Cb and Cr channels). Y is the brightness, Cb is blue minus Y (Blue - Y) and Cr is red minus Y (Red - Y). This format is better to image processing than RGB for several reasons [7][8]. The representative reason is that this model is less influenced by shadow because it has independent luminance channel Y. The conversion from RGB to YCbCr is defined by the following expressions:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \frac{1}{256} \begin{bmatrix} 65.738 & 129.057 & 25.064 \\ -37.945 & -74.494 & 112.439 \\ 112.439 & 94.154 & -18.285 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (5)$$

For the reasons, the input image is converted from RGB to YCbCr. Fig. 4 shows the input image in the dark and converted images. Since saturation is low in darkness, the chrominance channels show low contrast. Therefore, in this case, Y channel of converted image is used to TM.

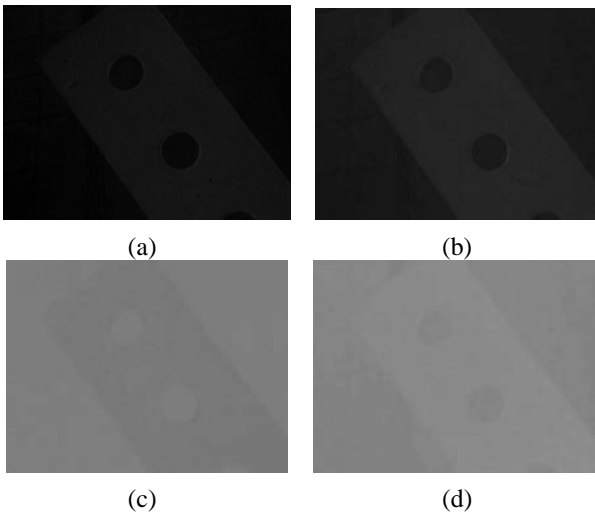


Fig. 4 (a) Input image in darkness; and each channel of the converted image: (b) Y channel, (c) Cb channel, (d) Cr channel

**4.2 Histogram analysis**

In the dark image, the contrast between the frame and background is enough to distinguish by brightness difference. In the bright image, however, they are hard to distinguish if the background color is similar to the frame. Therefore, the input image is processed in different ways based on its brightness. The brightness threshold is 50 of 255 gray-level set by experimental experience.

**4.3 Edge detection**

Edge detection removes disturbance information such as background of bolt holes. Canny method is sensitive edge detection compared with other methods [2]. So, Canny method is used to detect vague edges in this process.

Fig.5 shows different edges in Cb and Cr channel, but also common edges. By combining them as Fig. 6, the common edges emphasize the bolt holes and the differences help the commons to be looped.

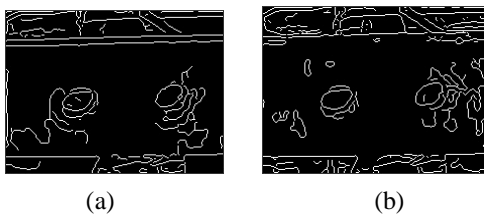


Fig. 5 Canny edge detections of Cb and Cr channels

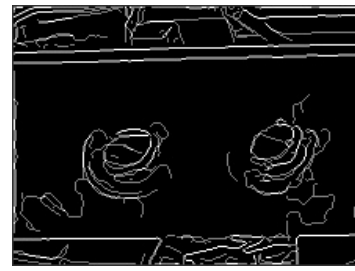


Fig. 6 Combined edges

**4.4 Template matching (TM)**

In this step, the preprocessed image and template are fast Fourier transformed and we use TM to create NCC image. The NCC image shows correlation between the preprocessed image and template. The template image is a simple filled circle as Fig. 7. The radius of circle is the same as desired one and calculated from the distance to steel frame.



Fig. 7 Template image created with given radius

Fig. 8 shows the NCC images as results of TM. The bright or dark part represents high correlation with template image.

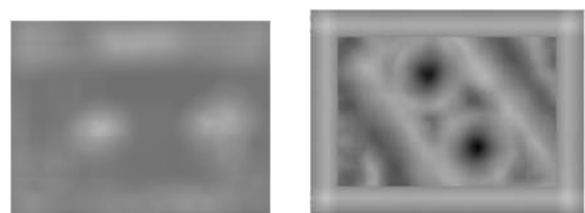


Fig. 8 Normalized Cross Correlation image

**4.5 Extraction of bolt holes**

Finally, the bolt holes are detected from the high-correlation parts, which are corresponding to the following conditions. All the values are set from experimental experience. (1) Their circularity is over 70% in brightness, over 80% in darkness. Eq. (5) is the circularity discriminant. (2) Their area is 30~90% of

desired circle. Because of remained disturbance information, the high-correlation part of bolt hole is smaller than desired circle.

$$circularity = \frac{4\pi \times Area}{perimeter^2} \quad (5)$$

## 5. EXPERIMENTAL RESULTS

Fig. 9 shows results of bolt hole detection with proposed method under the conditions that CHT cannot detect bolt holes at all. The detected bolt holes are marked with white circles. The proposed method detects precisely bolt holes under normal conditions.

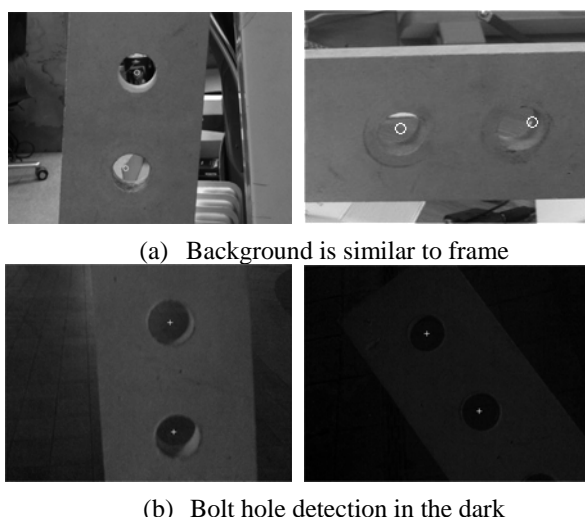


Fig. 9 Results of bolt hole detection

## 6. CONCLUSION

For the detection of bolt hole under various illuminations, we proposed a method by using YCbCr format and template matching. The experimental results show that the proposed method is successful to detect bolt holes under the conditions that CHT cannot detect. The proposed method allows the bolting robot free to operate under the illumination restraints.

## ACKNOWLEDGEMENT

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