Measurement of Relative Position between Spreader and Target Container with Image Processing (Proposal for Composition of New Template Image)

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Abstract: In this paper, we propose a composition method of the template image whose detection performance does not have incorrect detection and improves also on the tough photography conditions of the outdoors, rainy weather and night. This research was done to measure a relative position between a spreader and a target container with image processing to realize full-automatic quayside gantry cranes. By the proposal method, we confirmed that the template image for object detection has a contour image more effective than a gray image.

1. Introduction

As one of key technology for automation of loading and unloading operation of quayside gantry cranes, we are advancing research of a measurement method of a relative position between a spreader and a target container. We proposed the fundemental measurement method of the relative position in our previous work [1][2]. With cameras installed in the four corners of the spreader, we take images of each corner fitting's circumference on the upper surface of the target container. Next we detect the position of each corner fitting with template matching. Finally we calculate the relative position with plural position of corner fittings.

Since loading and unloading operation of quayside gantry cranes is done at outdoors, the change of the lighting conditions or surface state of corner fittings is large. As a result, the intensity distributions of corner fittings are varied. For this reason, it becomes a big subject how a template image to detect the corner fitting is composed.

Paying attention to the intensity distributions of corner fittings, we composed of two template images. And we had detected corner fittings well. However, it became clear that what has the same intensity distribution as corner fittings exists while processing much more images. It is the mark which specifically consisted of two white lines to show the storage position of a container on container terminals. Consequently, incorrect detection appeared here and there by the image taken at night in case of rainy weather.

In automation of quayside gantry cranes, detection of a corner fitting is impossible that is permitted, but incorrect detection is not allowed. Because, the safety of a crane is secured by a stop of a crane or intervention of an operator when detection is impossible. However, it is because a crane hangs up in incorrect detection, and it becomes the cause of the accident in the worst case.

Usually, since we had recognized corner fittings even if the intensity distribution of corner fittings changed, we thought that the essence of object recognition would be not the intensity distribution of the object but the contour which the object has. Therefore, the template image was composed from a contour image, the experiment which compares the result with the template image of the conventional intensity distribution, and the validity of the proposal technique was examined.

Chapter 2 describes the outline of the measurement method of the relative position between a spreader and a target container, and the composition of the conventional template image. Chapter 3 describes the composition of the new template image. In Chapter 4, the experiment result is described and we conclude this paper in Chapter 5.

2. Conventional Method

2.1 Measurement of Relative Position

Quayside gantry cranes are exclusive cranes for performing loading and unloading operation of containers between a container ship and a container track (Fig.1).

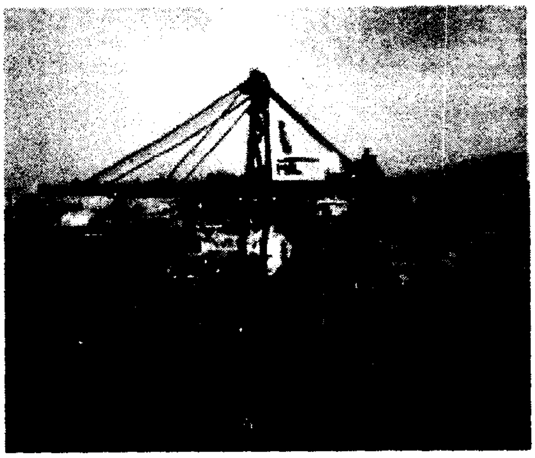


Fig.1. Quayside gantry crane

As for the present quayside gantry crane, development of various automation technology is promoted for the improvement in loading and unloading operation efficiency. In this research, the measurement method of the relative position is developed as one of key technology to handle containers automatically.

The outline of the measurement method is as follows. Cameras are installed in each corner of a spreader. Each camera takes an image of a corner fitting of a target container. Template matching based on the normalized correlation coefficient is performed to image data, and the position of the corner fitting is detected. Moreover, the relative position is calculated by them. The photograph of a spreader and a target container is shown in Fig. 2.

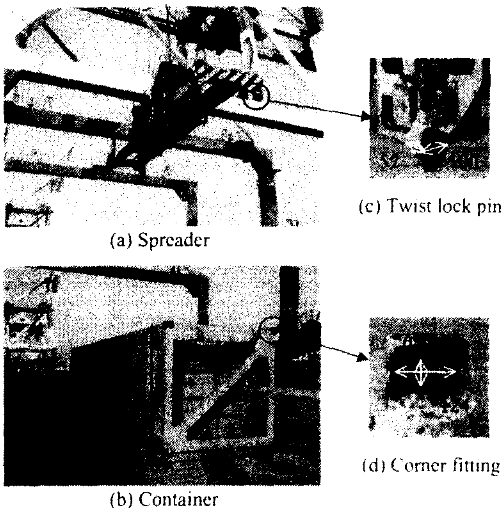


Fig.2. Photograph of a spreader and a target container

2.2 Corner Fitting Image

The example image of corner fittings are shown in Fig. 3. The image of corner fittings has normalized by 5[m] of photography distance, and size 41(H) 45(V)[pixel] .

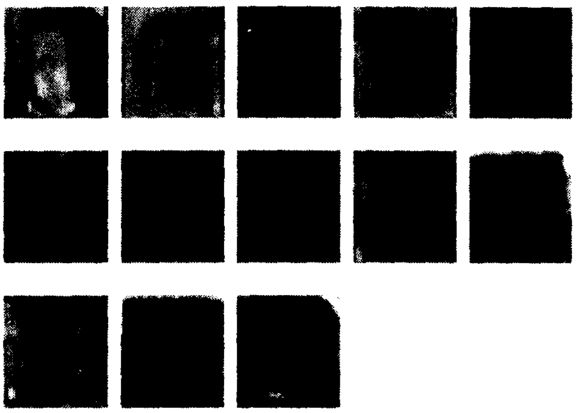


Fig.3 Example image of corner fittings

From these images, we can confirm the intensity distributions of corner fittings are diverse. The reason is as follows.

(a) Corner fitting itself: Painted in various colors. Paint tends to peel off by contact of a twist lock pin. The place where paint peeled off tends to rust.

(b) Outdoors condition: The surface of corner fittings shines, or it becomes a shadow. An intensity distribution changes by day and night, the weathers, etc.

(c) Change of photography distance: If the spreader approaches to a target container at night, an intensity distribution will change with lighting condition because of the shadow of a spreader.

2.3 Conventional Template Image

We can divide the image of corner fittings into two types. One is that the central intensity of corner fittings is higher than the circumference. The other is that the central intensity of corner fittings is lower than that. Then, paying attention to the central intensity distributions of corner fittings, two types of template image shown in Fig. 4 were composed.

(a) Basic template 1 (b) Basic template 2

Fig.4 Conventional template image

Basic template 1 (41 45[pixel]) is an average of 10 image data of to shown in Fig. 3. After Sobel differentiating Basic template 1, Basic template 2 (41 45[pixel]) is made by reversal processing of the intensity. Basic template 1 assumes detection of an area with the low intensity near the center of corner fittings. Similarly, Basic template 2 assumes detection of an area with the high intensity near the center of corner fittings. Val_1 and Val_2 are the maximum normalized correlation coefficient. Then, by the following formula, we can estimate the existence of corner fittings and the position on an Image are detected.

Priority 1st : If Val_1 > Thr_1
Basic template 1 is adopted.
Priority 2nd : If Val_1 Thr_1 Val_2 > Thr_2
Basic template 2 is adopted.
Priority 3rd : If Val_1 Thr_1 Val_2 Thr_2
There is no corner fitting candidate.
(1)

Where, Thr_1(=0.60) and Thr_2(=0.44) is threshold.

As we described in section 2.2, when a distance between a spreader and a target container becomes shorter, there is a problem to which the shadow of a spreader covers on the corner fitting, and makes the intensity distribution of the corner fitting change. The relation of the maximum normalized correlation coefficient with Basic template 1 when the corner fitting of Fig.3 changing the distance from 7[m] to 1[m] is shown in Fig.5. From this figure, if the distance becomes shorter, it can be confirmed that the maximum normalized correlation coefficient lowers. Therefore, the threshold of the conventional template image needed to specify low, in order to detect the corner fitting, even if the distance is shorter.

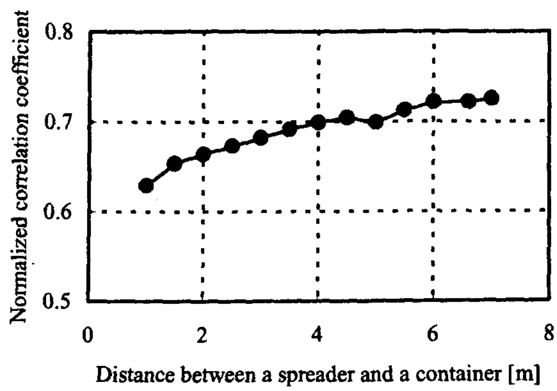
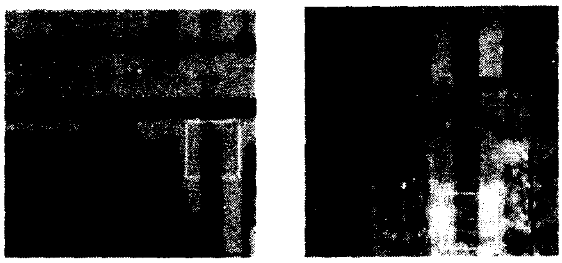


Fig.5 Relation between distance and normalized correlation coefficient

3. Problems

The image data of many containers were collected in container terminals, and template matching was performed by the conventional template image. Then, some incorrect detection of the mark composed two white lines to show the storage position of a container was found. The example of incorrect detection is shown in Fig. 6.



(a) Val_1=0.83　　(b)Val_1=0.65

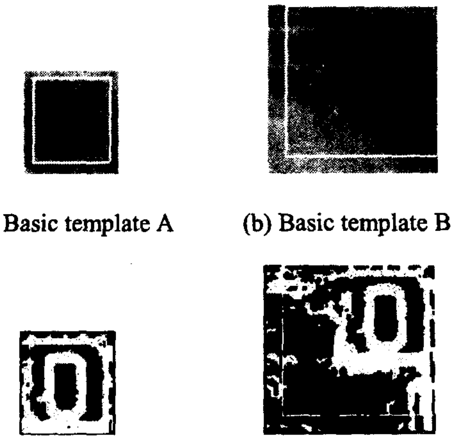
Fig.6 Example of incorrect detection

Fig. 6 (a) was what was taken in the daytime after rain, and the maximum normalized correlation coefficient with Basic template 1 is 0.83, and it incorrect-detected the domain of white lines within the limit. Fig. 6 (b) was what was taken at the night at the time of rainy weather, and the coefficient is 0.65, and it incorrect-detected similarly. These incorrect detections are not avoided in the threshold Thr_1(=0.60) of Basic template 1. Therefore, with the composition of the template image based on the intensity distribution, there is a problem that it cannot be coped with the image including the mark to show the storage position of a container on the conditions of rainy weather and night.

4. New Template Image

We can recognize corner fittings, even if the intensity distribution of corner fittings changes. So we can think the essence of our object recognition is not the intensity distribution of an object but the contour information of it. If it is contour information, fundamental information is kept even if lighting conditions etc. change.

On the other hand, the upper surface of corner fittings is a simple pattern consists of a rectangle and an ellipse fundamentally. For this reason, an object with a similar intensity distribution and a similar contour may exist in outdoor environment. Then, the corner fitting were independent case and the case where the contour of the corner fitting and the container of the circumference of it were made into the template image detecting the corner fitting, respectively. And we compared a detection performance. Furthermore, we evaluated the detection performance of the template image based on the intensity distribution. The new template image (inside of white lines) is shown in Fig. 7.



(a) Basic template A　　(b) Basic template B

(c) Basic Template C　　(d) Basic template D

Fig.7 New template image

Basic template A (41 45 [pixel]) is the same as that of the conventional Basic template 1. Basic template B (80 80 [pixel]) is the same image as Basic template A, and it is specified the domain widely so that the contour of the container including the corner fitting. Baisc template A is differentiated from Sobel operator. And it is performed binarization, consequently Basic template C (41 45 [pixel]) is made. Basic template D (80 80 [pixel]) is the same image as Basic template C, and it is specified the domain widely like Basic template B.

Based on the experiment result shown in the following chapter, the evaluation formula was created to the new template image of four sheets above.

5. Experiments

The normalized correlation coefficient with the new template image shown in Fig.7 was calculated to the image data of 32 totals. The statistical classification to the template image and detection results is shown in Fig. 8. The horizontal axis of Fig. 8 is a detection success (S) and failure (F) of the corner fitting in each template image. The average normalized correlation coefficient when succeeding detection of the corner fitting and the maximum normalized correlation coefficient when failing are shown in Table 1. From Table 1, the maximum normalized correlation coefficient when failing of Basic template A is larger than the coefficient when succeeding detection of the corner fitting, and we can confirm that it is not suitable as the template iamge. That is, the problem was in detection of the corner fitting only by the conventional template image.

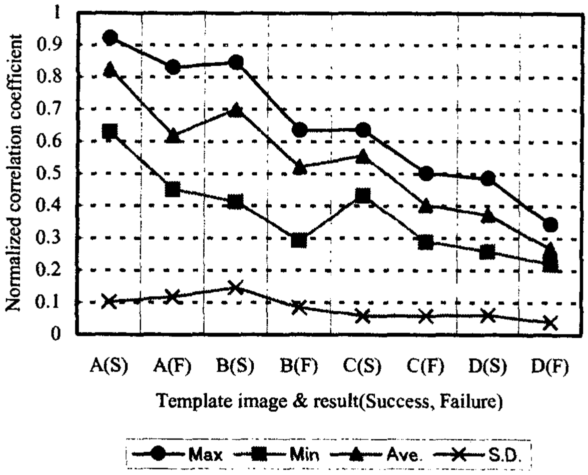


Fig.8 Statistical classification for template images and their result (Success or Failure)

Table 1 Result of normalized correlation coefficient

	Ave. of Success	Max of Failure
Template A	0.82	0.83
Template B	0.70	0.63
Template C	0.56	0.50
Template D	0.37	0.34

It is necessary to set the maximum normalized correlation coefficient which failed in detection by each template image to prevent incorrect detection of the corner fitting as a threshold from Fig. 8.

The number of detection success of the corner fitting is shown in Table 2 according to a total of 32 image data. In Table 2, "Success" is a total number of detection success, "Threshold" is the number of detection success in case a normalized correlation coefficient is beyond the threshold. "Rain" is the number of detection success in case a normalized correlation coefficient is beyond the threshold and rainy weather. In addition, the number of detection success of the corner fitting is a total of 20.

Table 2 Number of successful detection

	Success		Rain
Template A	13	8	0
Template B	13	10	1
Template C	17	14	1
Template D	19	14	5

When the template image of four sheets shown in Fig. 7 is independently evaluated from Table 2, Basic template D is the best and the order of following C, B and A. From this experimental results, we can confirm that a contour image is more effective than a gray image by the object detection with template matching on the tough photography conditions of rainy weather, the outdoors and night.

However, there are few detectable corner fittings only at Basic template D. Then, it decided to detect the corner fitting combining two or more template images shown in Fig. 7. The evaluation formula obtained below is shown.

Priority 1st : If Val_D > Thr_D
Basic template D is adopted.
Priority 2nd : If Val_C > Thr_C
Basic template C is adopted.
Priority 3rd : If Val_B > Thr_B
Basic template B is adopted.
Priority 4th : If Val_A > Thr_A
Basic template A is adopted.
Priority 5th : If except the above
There is no corner fitting candidate.
(2)

Where, Val_D is the maximum normalized correlation coefficient calculated by Basic template D. Val_C, Val_B, and Val_A are the same as Val_D. Thr_D (=0.34) is the threshold of Basic template D. Thr_C (=0.50), Thr_B (=0.63), and Thr_A (=0.83) are the same as Thr_D. 14 sheets are detectable by Basic template D among the image data of 20 sheets in which detection of corner fittings succeeded. Five sheets are detectable by the following Basic template C. And one sheet is detectable by the following Basic template B. Basic template A is originally needlessness in this experiment result, but the average normalized correlation coefficient is higher, so we have left it as Priority 4th by the evaluation formula.

6. Conclusion

In template matching, we compared the template image of a contour image with that of a conventional gray image. Consequently, we confirmed that the template image of a contour image was more effective on the tough photography conditions such as rainy weather, the outdoors and night. Moreover, we combined the template image of a contour image and a gray image, and realized the composition method of the template image to do not have incorrect detection and improve the detection performance.

References

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