Object Detection Scheme Using Cross Correlation and Affine Transformation Techniques

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Abstract

In object recognition, there are several situations which may cause object image detection failure including that the object zooming in, zooming out, rotated, mirror, or something deformation and the object sizes become irregular. In this paper, an object normalization technique used to make the object into standard, an affine transform technique make the same object to meet any irregular shape, and a cross-correlation technique used to judge which object is most resemble. After over 200 test images that include different shapes, styles, size and colors used in simulations, this scheme is proven to achieve 100% object image detection.

Keywords: affine transform, cross-correlation, segmentation, normalization, object detection

1. Introduction

Machine vision and image identification is a powerful tool which is widely employed in automatic monitoring and objects detection processes. Many machine vision applications [1-2] have been proposed for dice gambling machines, it can identify the numbers of spots in a dice cluster automatically. Correia et al. [2] proposed a algorithm which can automatically detect and classify the dice scores on casino playing tables. They based on the online analysis of images captured by a monochrome CCD camera to extract the dice pips. This is an object identification application case.

Face identification is a kind of object detection. Yang and Huang [3] used a hierarchical knowledge-based method to identify faces. They adopt the three level resolutions techniques to achieve the goal. The lowest resolution image was used for searching face candidates area. At the medium resolution image, a local histogram equalization technique was performed on the face candidates. Meanwhile, the surviving candidate regions were then picking up at the highest resolution associated with a set of facial features. The benefit of this method is that a coarse-to-fine strategy can reduce the computation.

Leung et al. [4] based on local feature detector and random graph matching to propose a probabilistic method to find a face out in a scene. In his method, five features; two eyes, two nostril, nose and lip junction were used to define a typical face features. At the same time, a facial template was created. The relative distances of any pair of facial features of the same type were calculated to examine whether the testing object is a human face or not.

Badenas and Pla [5] proposed a approach for segmenting and tracking moving objects. In the article, they integrated segmentations by frame-to-frame process, and accumulated the segmentation information to achieve a segmentation improved. This procedure does not only get the tracking of objects, but also enhanced the segmentation itself once the tracking has been performed.

Alexander et al. [6] research similarity criteria between non-rigid shapes. In fact, such criteria are divided into the intrinsic and extrinsic. The metric structure of the objects and the geometry of the shapes using Euclidean space both have their advantages and disadvantages. Extrinsic similarity is sensitive to non-rigid shapes deformations, but intrinsic similarity is sensitive to topological noise. In their scheme, they present an approach unifying both criteria from a single distance. Experimental results reveal the robustness of their approach in cases where using only extrinsic or intrinsic criteria fail.

There are many papers regarding the object recognition using neural, fuzzy and image processing identification [7-9]. Several proposed papers about affine transform can be seen in [10-12]. Besides, the papers that using cross-correlation techniques can be find in [13-15]. In this paper, we use the affine transform and cross correlation techniques to construct an effective object image recognition scheme. In our scheme, it can be used to identify and distinguish the objects, like dice, chess and different shape objects. The remainder of this paper is organized as follows. In Section 2, the relative work is reviewed. In section 3, we present the detection algorithm. The empirical tests are shown in Section 4. Finally, a conclusion of this paper is shown in Section 5.

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2. Relative Works

2.1 Affine Transformation

In many imaging processing systems, objects detection are subject to geometric deformation introduced by perspective irregularities wherein the position of the camera with respect to the scene change the apparent dimensions of the scene geometry. Applying an affine transformation to a uniformly distorted image can correct for a range of perspective distortions by transforming the measurements from the ideal coordinates to those actually used.

An affine transformation technique is a kind of any transformation that preserves ratios of distances and co-linearity. This method composes self and must be a 2D affine transformation with a rotation through a given angle in radians. Usually, the center of rotation is the origin. While an affine transformation preserves proportions on lines, it does not necessarily preserve lengths or angles. Any triangle can be transformed into any order by an affine transformation, in the sense; affine is a congruent generalization. The equation of the affine transform can be written as the formula (1). It is also can be written as the formula (2)

$$t\begin{bmatrix} x' \\ y' \end{bmatrix} = s\begin{bmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{bmatrix}\begin{bmatrix} x - x_0 \\ y - y_0 \end{bmatrix} \qquad (1)$$

$$\begin{aligned} x' &= ax - by + c \\ y' &= bx + ay + d \end{aligned} \qquad (2)$$

Where

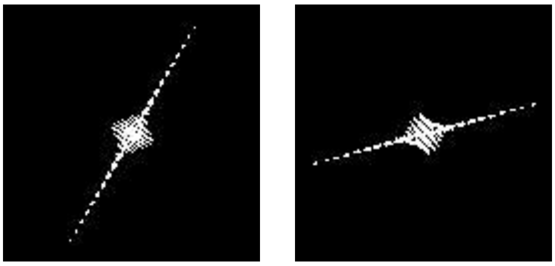
$$a = s\cos\alpha \qquad (3)$$

$$b = -s\sin\alpha \qquad (4)$$

$$s = \sqrt{a^2 + b^2} \qquad (5)$$

$$\alpha = \tan^{-1}(-b/a) \qquad (6)$$

In this paper, we used the affine transformation to rotate the shape of the input object each by 10 degrees as a test for object compare with the standard objects of the database. Fig. 1 shows the example of the object after affine transform operation. Fig.1(a) is a test object shape and Fig.1(b) shows the object shape after affine transform operation. Fig. 1 revels the same object may be have different shape and position in the picture but it still can be solve by affine transformation technique.



(a) (b)

Figure 1: The affine transform example; (a) an object shape, (b) the object shape after affine transform operation

2.2 Cross Correlation

The cross-correlation of two real continuous functions r_{xy} is defined by formulas (7) and (8) and listed it below.

$$r_{xy}(\tau) = \int_{-\infty}^{\infty} x(t)y(t+\tau)dt = r_{yx}(-\tau) \qquad (7)$$

$$r_{yx}(-\tau) = \int_{-\infty}^{\infty} y(t)x(t-\tau)dt \qquad (8)$$

Where r_{xy} is the cross-correlation function, $x(t)$ and $y(t)$ are the real continuous signal.

In fact, the $x(t)$ and $y(t)$ are the finite length signals therefore the cross-correlation function can be express as the formula (9)

$$r_{xy}(\tau) = \frac{1}{T}\int_{0}^{T} x(t)y(t+\tau)dt \qquad (9)$$

For the discrete time signal of the two finite length signal, $x(t)$ and $y(t)$, the cross-correlation function can be calculated by formulas (10) and (11), and shown in below.

$$r_{xy}(i) = \frac{1}{N}\int_{n=0}^{N-1} x(n)y(n+i) = r_{yx}(-i) \qquad (10)$$

$$r_{yx}(-i) = \frac{1}{N}\int_{n=0}^{N-1} y(n)x(n-i) \qquad (11)$$

Usually, we confined the range in +1 or -1 of the results during measuring the correlation of the two signals. +1 express 100% positive correlation, -1 denotes the negative correlation and 0 indicates zero correlation. The zero correlation means the two signals are independence, did not have any relation. Formula (12) is used to normalize the cross-correlation; and it is the equation to transfer the value into -1 or +1.

$$\rho_{xy}(i) = \frac{r_{xy}(i)}{\frac{1}{N}\left[\sum_{n=0}^{N-1} x^2(n) \sum_{n=0}^{N-1} y^2(n)\right]^{1/2}} \qquad (12)$$

Where, $\rho_{xy}(i)$ is the cross-correlation coefficient and i is the control variable.

3. The Detection Algorithm

Object detection is a powerful tool which is widely employed in automatic detection processes. In this paper, we focus on developing an effective and simple algorithm for automatically identifying the object images. Fig.2 shows the flow chart of our developing algorithm. Due to object identifying, the standard database is needed for object comparison. Thus, there are two pass in our scheme; one is the standard object creation, the other is the input object identification. The process of the two passes almost all the same except the data storage or comparison. In the standard database creation step, the standard object patterns are used as the test input. And then the image preprocessing stage is used to filter out the noise and improve the object precision. The small object size discard is adopted to eliminate those bigger noises. Owing to the object comparison is on any orient, so that the object center is used to calculate the angle of the rotation. However, the objects have zooming in and zooming out problems. Thus, a normalization stage is necessary used to let the object size standardized. Once all the objects are on the standard, then the objects comparison operation can be achieved corrective judging and find out the exact object. On the other hand, because there are several objects in the image, an object extraction step used to distinguish the objects is necessary. Furthermore, we use the affine transform technique to change the object shapes and used the cross correlation technique to calculate the relation score. After all the scores are obtained, the object decision stage is used to judge the objects and the object detection is accomplished. The details of the object detection are described in the following.

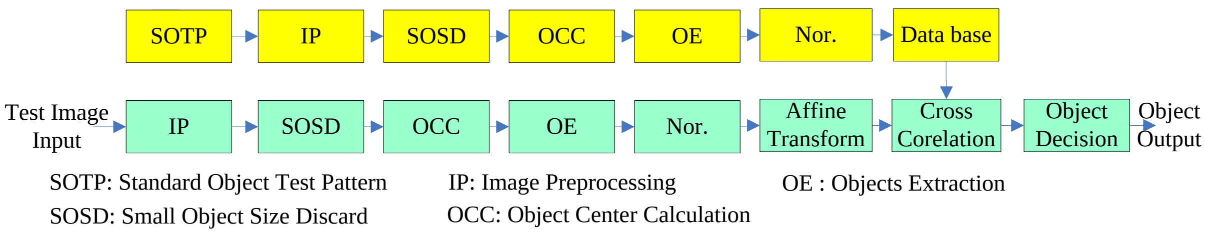


Figure 2: The object detection algorithm

3.1 Image Pre-processing

For filter out the noise and improving image detection accuracy, a pre-processing step is necessary. Fig. 3 shows the image preprocessing flow chart. In image preprocessing, we first use the RGB2YIQ stage to transfer the color image in RGB planes into YIQ planes. And then the Y plane was selected used as the grayscale image for further image processing. To speed processing, an image binarizing (IB) operation is hired to convert the gray-scale image into a binary format. Since Otsu method is an efficient and convenient method, it is suitable for binarization. Besides, we use the opening operation to eliminate the noise and the small object deleted stage was adopted to eliminate those bigger noises and leave the real objects. Meanwhile an object labeling (OL) stage is used to mark and count the number of objects in the image.

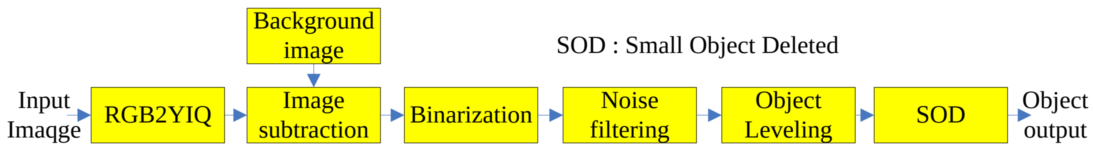


Figure 3: Image preprocessing flow chart

3.1.1 Color Transform RGB2YIQ

The color red, green and blue (RGB) are three dimensions of illumination spectrum. They are enough to create any color effectively, although the spectrum of illumination is infinite dimensional. A common alternation to the RGB express of an image is the YIQ planes. The YIQ representation of an image is the standard model in the television signal. The formula (13)-(14) are the transform equation and inverse transform equation for color transform and listed it below.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.596 & -0.274 & -0.322 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (13)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.000 & 0.956 & 0.621 \\ 1.000 & -0.272 & -0.647 \\ 1.000 & -1.106 & 1.703 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix} \quad (14)$$

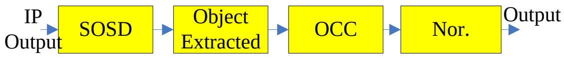
Where Y is the brightness which refers to color density, I is the hue which is the dominant one such as red, orange or yellow, and Q is the depth which is the amount of white light mixed with a hue of color. The equation (14) is the inverse transformation of equation (13), and used to transfer the image in YIQ planes back into the RGB planes.

3.2 Object Extraction and Normalization

After image preprocessing, the candidate objects are obviously and easier to extract. Owing to the small object is the bigger noise, thus we use the small object deleted stage to remove those noise. In general, the objects might scatter on the frame, the labeling stage is necessary used to indicate the each one object. Certainly, by mean of the labeling technique and object extracting conduct, the objects are all extracted correctly. Since the objects image is capture by the camera, therefore, have existing the zoom in and zoom out problems. In order to make up the drawback, a normalization stage is used to standard the objects. At the system beginning, we select an object size A_s as a standard. During the system operation, we compare the input object size A_i with the standard A_s to get the multiplying ratio K. And then we multiply the input object with K to achieve the normalization target. The formula (15) is the normalization equation. Before the normalization step, we calculate the object center use as the base point for object multiplying. This action will cause a perfect effect for the object standardized with smooth. Fig. 4 shows the flow chart of the object extraction and normalization.

$$K = \frac{A_i}{A_s} \quad (15)$$

Where, K is the multiplying ratio; the rate is the object zoom-in or zoom out. A_i express the area of the input object and A_s denote the area of the standard object.



SOSD: Small Object Size Discard
OCC: Object Center Calculation

Figure 4: The flow chart of the object extraction and normalization

3.3 Object Decision

In object decision, the object number of the image is first to compute because it is used to decide how many times the system needed to be executed of the object compare with the database. In initialization, we set the object number N to the control signal to decide the execute loop of the comparison program. N mean run the program N times, and run each time the N is mine 1. Until the N is equal to zero, the algorithm will stop and output the results of the system comparison.

Once the object number has decided, the details of the object recognizing need to be made. In affine transform, we rotate the object image into 72 computation times corresponding to the 360 degree of object pattern. This action can solve the objects shape is on scatter, means we calculate the cross correlations coefficient ρ_{xy}. In cross correlation step, we check the size match ratio of the input object and standard database. If the pattern size match ratio is greater than the threshold, we judge the pattern is the same the standard. The judge formula is shown in the equation (16). The details of the object decision flow chart can be seen in Fig. 5.

$$\rho_{xy}(i) \geq S_{th} \quad (16)$$

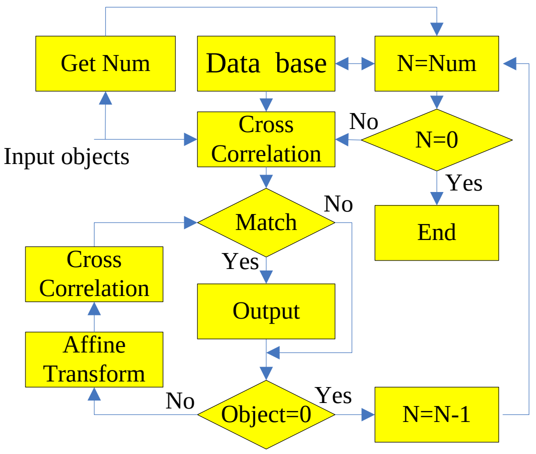


Figure 5: the flow chart of the object decision

4. Experimental Results

For demonstrating the performance of the proposed scheme, we use 200 test images that include different styles, sizes, shapes and noise with size 640×480 pixels for simulation. In the experiment, many combinations of different object are selected to test. Several test states wherein locations of object are scattered or regular are included. On the other hand, we zoom in and zoom out from the image for examining the algorithm's identification ability. In order to test robustness, different cameras, different sizes, different amounts of noise and different permutations are used in the simulations.

For demonstrating the effect of our scheme, the simulation results are shown in Fig. 6 ~ Fig.11. Fig. 6 shows the used in simulation objects include square image, circular image, heart-shaped image hexagonal image and triangles image. Fig. 6(a) is the original test image with color, figure 6(b) is the grayscale image corresponding to the figure 6(a). Fig. 7 shows test images case-1. Its pattern includes the objects of heart-shaped image and hexagonal image are rotated 90 degree others hold the same as the standard test image shapes. Fig. 7(a) is the color test image and Fig. 7(b) is the binary image with the object labeling corresponding to the figure 7(a). It shows the object extracted of the input image by image processing. From Fig. 7(b), we see the content have total 5 objects. We first compare the circular pattern denote number 1 with the data base. We recode the match ration and check it with threshold. If the pattern size match ratio is greater than the threshold (0.8) , then we judge the pattern is the same the standard comparison object and output it. We move the objects which are detected and then examine the next object. By the rule, one after one detected. Up to all the objects are all compared, we change the standard compare target to next object means we examine the circular pattern on the data base. According this rule, we check the objects in the input image in turn and extracted its shape from the data base. Fig. 7(c) shows all detected objects. Table 1 list all comparison ration results of the between input image and data base pattern corresponding to the figure 7. After carefully check the comparison ration results, we make sure our scheme can exactly to identify the objects of the input image.

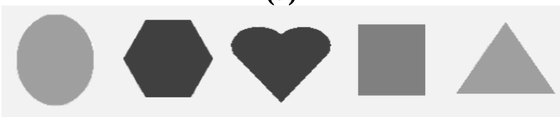
Fig. 8 is the test image case-2. In the image, the square pattern is rotated 10 degree and triangles pattern is rotated 20 degree, meanwhile, the image was 30% noise added. Fig. 8(a) shows the original test image and Fig. 8(b) display the bainary image with the object labeling of the 8(a). Fig. 8(c) express the simulation results of the 8(a), they are all obtain the correct detection. Table 2 show the detetion results of the Fig.8. from the results, we see the cross corelation ration are above 0.93134 grate than the threshold (0.8).

Fig. 9 shows the enlarged test image case-3; it include the square pattern is rotated 30 degree, the heart pattern is rotated 90 degree and hexagonal pattern is rotated 90 degree under 30% noise added. Fig. 9(a) is the original test imagen and Fig. 9(b) shows the bainary image with the object labeling of 9(a). Finally Fig. 9(c) dislay the correct results from the simulation detection. Table 3 shows the cross corelation coefficient of the match object is 0.97124 otherwise are 0.75907, 0.51365, 0.62876 and 0.44703 are all less than threshold (0.8) for the circle object. For column 2, its target is find out the hexigonal shape. The cross-corelation coefficients are 0.92296, 0.60308, 0, 0.69138, 0.51037. it is obviousely to find the object label number 1 is the target. The value 0 means the object is exclusive because the shape already matched with last object.

Fig. 10 shows the enlarged test image case-4; it include the square pattern is rotated 50 degree, heart pattern is rotated 90 degree and hexgonal pattern is rotated 30 degree under 40% noise added. Fig. 10(a) is the original test image and Fig. 10(b) is the bainary image with the object labeling corresponding to the Fig. 10(a). Fig. 10(c) shows the detection results, it is obviously the system got correct detection. On the other hand, the table 3 diplay the correlation coefficient of each objects. From the table, we see the correlation coefficients are the 0.9712, 0.92296, 0.97659, 0.98274 and 0.97061, are all easier to distingished from other objects.

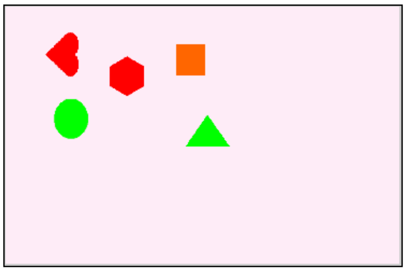
Fig. 11 shows the shrink test image case; it is include the square pattern is rotated 50 degree, heart pattern is rotated 90 degree, hexagonal pattern is rotated 90 degree and triangles pattern is rotated 20 degree under 40% noise added. Table 5 display the simulation results, it is obviously the objects are correctly detected.

(a)

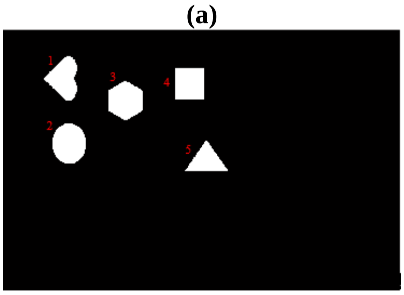


(b)

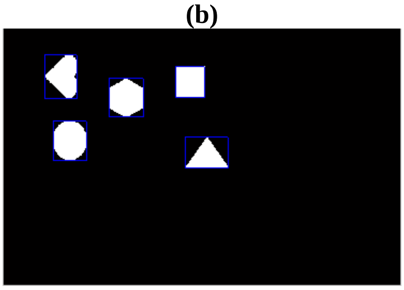
Figure 6: the objects used to simulation, (a) the original test images, (b) the grayscale images of the (a)



(a)



(b)

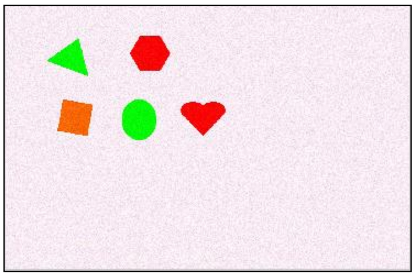


(c)

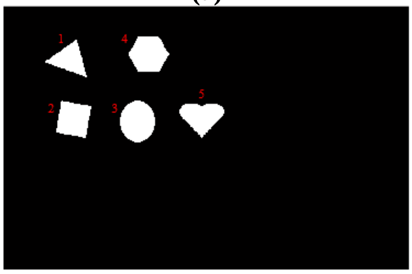
Figure 7: the test image case-1; the heart-shaped image and hexagonal image are rotated 90 degree; (a) the original test image, (b) the binary image with the object labeling, (c) the correct detected object.

Table 1: the cross correlation coefficients of the between input image and data base pattern corresponding to the figure 7.

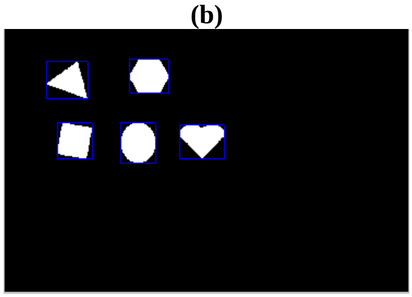
	1	2	3	4	5
1	0.50641	0.98754	0.75848	0.34229	0.43937
2	0.61432	0	0.93134	0.37212	0.50688
3	0.99709	0	0	0.39237	0.54703
4	0	0	0	1	0.61838
5	0	0	0	0	1



(a)



(b)

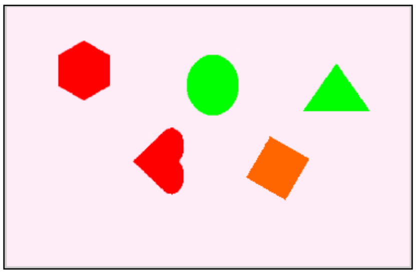


(c)

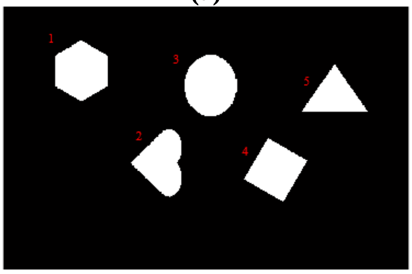
Figure 8: the test image case-2; the square pattern is rotated 10 degree and triangles pattern is rotated 20 degree under 30% noise added; (a) the original test image, (b) the bainary image with the object labeling, (c) the correct detected object .

Table 2: the cross correlation coefficients of the between input image and data base pattern corresponding to the figure 8.

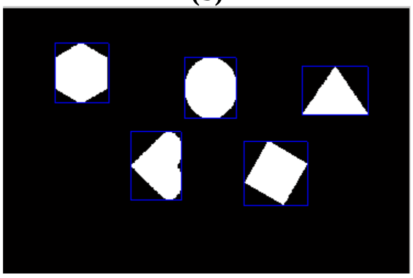
	1	2	3	4	5
1	0.50641	0.98754	0.75848	0.34229	0.43937
2	0.61432	0	0.93134	0.37212	0.50688
3	0.99709	0	0	0.39237	0.54703
4	0	0	0	1	0.61838
5	0	0	0	0	1



(a)



(b)

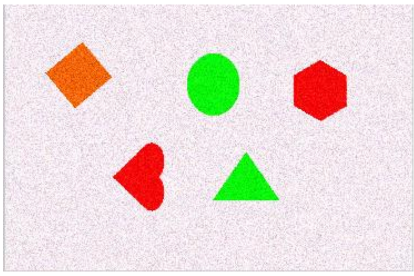


(c)

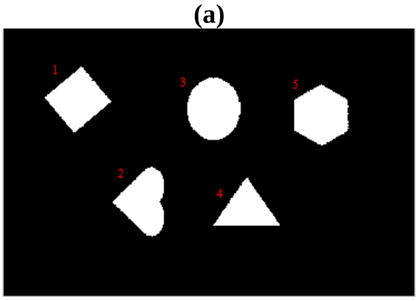
Figure 9: the enlarged test image case-3; the square pattern is rotated 30 degree, the heart pattern is rotated 90 degree and hexagonal pattern is rotated 90 degree under 30% noise added; (a) the original test image, (b) the bainary image with the object labeling, (c) the correct detected object .

Table 3: the cross correlation coefficients of the between input image and data base pattern corresponding to the figure 9.

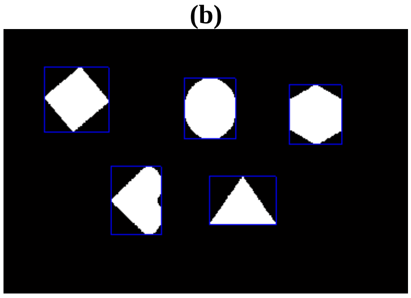
	1	2	3	4	5
1	0.75907	0.51365	0.97124	0.62876	0.44073
2	0.92296	0.60308	0	0.69138	0.51037
3	0	0.97659	0	0.68515	0.55127
4	0	0	0	0.98274	0.61841
5	0	0	0	0	0.97061



(a)



(b)

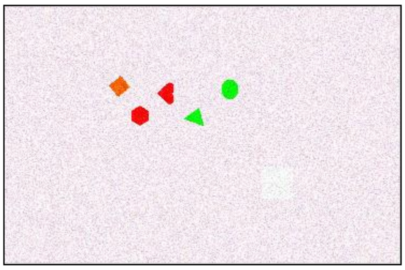


(c)

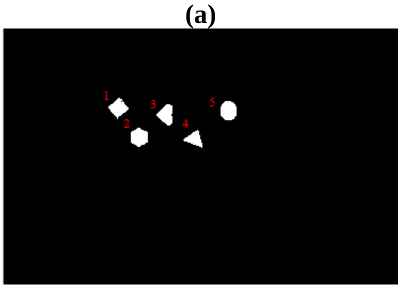
Figure 10: the enlarged test image case-4; the square pattern is rotated 50 degree, heart pattern is rotated 90 degree and hexgonal pattern is rotated 30 degree under 40% noise added; (a) the original test image, (b) the binary image with the object labeling, (c) the correct detected object .

Table 4: the cross correlation coefficients of the between input image and data base pattern corresponding to the figure 10.

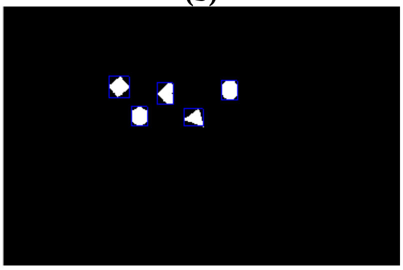
	1	2	3	4	5
1	0.60406	0.51369	0.9669	0.44096	0.75221
2	0.65607	0.60329	0	0.51111	0.96583
3	0.65079	0.97499	0	0.55057	0
4	0.84935	0	0	0.61828	0
5	0	0	0	0.96906	0



(a)



(b)



(c)

Figure 11: the shrink test image case-5; the square pattern is rotated 50 degree, heart pattern is rotated 90 degree, hexagonal pattern is rotated 90 degree and triangles pattern is rotated 20 degree under 40% noise added; (a) the original test image, (b) the binary image with the object labeling, (c) the correct detected object .

Table 5: the cross correlation coefficients of the between input image and data base pattern corresponding to the figure 11.

	1	2	3	4	5
1	0.60976	0.77277	0.51229	0.33685	0.91921
2	0.66644	0.89295	0.59881	0.39977	0
3	0.65217	0	0.9376	0.53946	0
4	0.84483	0	0	0.5583	0
5	0	0	0	0.93897	0

5. Conclusions

In this paper, an object normalization technique used to make the object into standard, an affine transform technique make the object to meet any scatter states, and a cross-correlation technique used to detection which object is most resemble. In system simulation, we use 200 test images that include different styles, sizes, and shapes and add noise; we obtain 100% corrective detection.

In Fig. 6, the square pattern is rotated 10 degree and triangles pattern is rotated 20 degree, meanwhile, the image was 30% noise added. we see the cross corelation ration are above 0.93134 grate than the threshold. In Fig. 7, the square pattern is rotated 30 degree, the heart pattern is rotated 90 degree and hexagonal pattern is rotated 90 degree under 30% noise added. The cross-corelation ration are 0.92296, 0.60308, 0, 0.69138, 0.51037. it is obviousely to find the object label number 1 is the target. From the experimental results, it is show that no matter what the test include zoom in, zoom out, noise added, out scheme all can exactly detect the objects.

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