The safety helmet detection for ATM' s surveillance system via the modified Hough transform

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ABSTRACT

The Automatic Teller Machine (ATM) plays an important role in the modern economical activity. It provides a fast and convenient way to process economical transactions between banks and their customers. Unfortunately, it also provides a convenient way for criminals to get illegal money. For the safety reason, each ATM is with the surveillance system to record customer's face information. However, when criminals use the ATM to withdraw illegal money, they usually hide their faces with something (e.g. safety helmets) to avoid that the surveillance system records their face information. That will make the surveillance system decrease their efficiency. In this paper, we propose a circle/circular arc detection method based upon the modified Hough transform, and apply it to the detection of safety helmet for the surveillance system of the ATM. Since the safety helmet location will be in the set of the obtained possible circles/circular arcs (if any exists). We use geometric features to verify if any safety helmet exists in the set. The proposed method can be applied to the surveillance systems of ATM's and banks, and it can provide the early warning to save-guards when any "customer" tries to avoid his/her face information from surveillance, such as withdrawing money with the safety helmet. That will make the surveillance system more useful. A real ATM image is used to see the performance of proposed method.

Keywords: Safety Helmet Detection, Modified Hough Transform, Circle/Circular Arc Detection.

1. INTRODUCTION

he Automatic Teller Machine (ATM) plays an important role in the modern economical activity. It provides a fast and convenient way to process economical transactions between banks and their customers. Unfortunately, it also provides a convenient way for criminals to get illegal money. When using the ATM, a customer will be asked to input his/her bankcard and password for personal idenification. Besides, for the safety reason, each ATM is with the surveillance system to record customer's face information. However, when criminals use the ATM to withdraw illegal money, they usually hide their faces with something (e.g. safety helmets) to avoid that the surveillance system records their face information. That will make the surveillance system decrease their efficiency.

The Hough transform (HT) [1] has been widely used for pattern (such as straight line, circle, ellipse, etc.) detection [2]. The drawback of the traditional HT is the large computation and storage requirement. This drawback makes the traditional HT difficult to the practical application. Many techniques have been provided to improve the traditional HT, such as the fast Hough transform (FHT) [3] and adaptive Hough transform (AHT) [4]. They changed the processed image from one resolution into multi-resolution, and increased the efficiency of SHT. However, the quantization error will be extended in various resolution scales. Recently, the probability concept was used to modify SHT, such as the probabilistic Hough transform (PHT) [5] and the randomized Hough transform (RHT) [6]. PHT and RHT reduce the computation and the storage requirement by the probability. However, they can't always extract the patterns successfully, because of the probability error. The modified Hough transform (MHT) for line detection [7] was proposed to improve the probability problem of RHT and PHT. However, MHT was not proposed for circle or circular arc detection.

For the circle detection, a method through a 2D Hough transform and radius histogramming was proposed [8]. They voted each mid-perpendicular of two point pairs to obtain the centers of the circles, and computed the distance between each point and the extracted center to obtain the radius. The center detection may be failed when the image is complicated or corrupted with noise. However, their method is not proposed for circular arc detection. Pei and Horng proposed a method based on HT to detect circular arcs [9]. Their method needs to execute HT computation twice: the first computation is for detecting the contours which arc lies upon; while the second one is for obtaining the parameters of the arcs from the near-peak HT data. However, the main drawbacks for applying the HT technique are the requirement for the huge memory storage capacity and tedious computation time. These drawbacks make HT difficult to be applied in real-time detecting procedures.

In this paper, we propose a circle detection method (we call it the modified Hough transform) and apply it to the circle/circular arc detection. Since the safety helmet location will be in the set of the obtained possible circular arcs (if any exists). We use the geometric features to verify if any safety helmet exists in the set.

2. ALGORITHM

2.1. Modified Hough transform for circle detection

The steps of the MHT for the circle detection are summarized as follows:

Step 1. Seed point selection: Given an image (image size= $W \times H$), and there are N edge points,

$$P = \{p_i = (x_i, y_i) \mid i = 1,2,\ldots,N\}. \quad (1)$$

We pick each point (p_i) from P to be the seed point. D is the distance voting space. D is used to store the points whose distance to the current seed point is d, i.e.

$$D(d) = (x_k, y_k). \quad (2)$$

When a new seed point is selected, D is set to be *NULL*. The memory for D can be reused for next seed point.

Step 2. Distance voting: In this step, we use the distance voting to select three points that may form a circle. In Fig. 1, assume $p_1=(x_1, y_1)$, $p_2=(x_2, y_2)$, and $p_3=(x_3, y_3)$ form a circular arc, and p_2 is the midpoint of the arc, we can obtain $\overline{p_1p_2} = \overline{p_2p_3}$, i.e., assume the seed point is the midpoint of a circular arc, there will exist two points whose distances to the seed point are the same. When a seed point, $p_i=(x_i, y_i)$, is selected, we compute the distance (d) between p_i and other points, p_j, in P, i.e.

$$d = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}. \quad (3)$$

If $D(d)$ is *NULL*, we set $D(d)=(x_j, y_j)$; otherwise, we use these three pints, p_i, p_j and the point in $D(d)$ to obtain the circle's parameters (x_c, y_c, r_c) in next step.

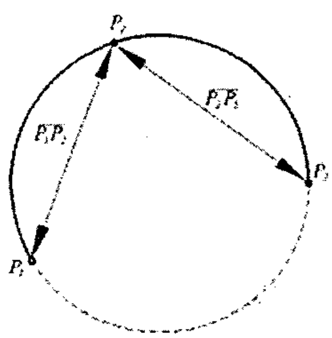


Figure 1: An example for three points on a circle. If there are two points, p_1 and p_3, and their distance to the midpoint, p_2, are the same, then these three points may form a circle.

Step 3. Parameter computation: Since all mid-perpendiculars formed by any two points of a circle intersect at the center of the circle, we can obtain the circle parameters (x_c, y_c, r_c) from mid-perpendiculars.

One mid-perpendicular formed by p_1 and p_2 can be described by its slope (a_1) and the midpoint (b_1) of $\overline{p_1p_2}$:

$$a_1 = -\frac{x_2 - x_1}{y_2 - y_1}, \quad (4\text{-a})$$

and

$$b_1 = \frac{y_1 + y_2}{2} - a_1\frac{x_1 + x_2}{2}. \quad (4\text{-b})$$

Similarly, the other mid-perpendicular formed by p_2 and p_3 can be described by its slope (a_2) and the midpoint (b_2) of $\overline{p_2p_3}$:

$$a_2 = -\frac{x_3 - x_2}{y_3 - y_2} \quad (5\text{-a})$$

and

$$b_2 = \frac{y_2 + y_3}{2} - a_2\frac{x_2 + x_3}{2}. \quad (5\text{-b})$$

Since the center (x_c, y_c) of the circle formed by p_1, p_2 and p_3 is also the intersection point of two mid-perpendiculars (Eqs.4 and 5), we can obtain

$$x_0 = \frac{b_2 - b_1}{a_1 - a_2} \quad (6\text{-a})$$

and

$$y_0 = a_1x_0 + b_1. \quad (6\text{-b})$$

The radius of the circle can be obtained by

$$r_0 = \sqrt{(x_1 - x_c)^2 + (y_1 - y_c)^2}. \quad (7)$$

Step 4. Parameter voting: We set a parameter space to record the parameters from the step 3. If (x_0, y_0, r_0) doesn't exist in the parameter space, we create a new record, (x_0, y_0, r_0), in the parameter space, and set the initial value of the record accumulator to be 1; otherwise, we add 1 to the existed accumulator of (x_0, y_0, r_0).

If all edge points in P are picked as the seed point, the process is finished and circles in the image can be obtained from the peak position in the parameter space; otherwise, go back to the step 1.

2.2. Circular arc detection

If the patterns are circular arcs, they will lie on the circles found from above circle detection steps. We apply geometric methods to estimate parameters of a circular arc. The parameters include the center coordinates (x_0, y_0), the radius (r_0), the angle of the start point to the x-axis (θ_s) and the angle of the end point to the x-axis (θ_e) (see Fig.2).

When one set of circle candidate parameters, (x_0, y_0, r_0), is obtained, we extract edge points "around" the circle, i.e., we take all points that satisfy

$$\left|(x - x_o)^2 + (y - y_o)^2 - r_0^2\right| \le 1, \quad (8)$$

and put them into S (the set of points on the circular arc). The gray-level value, $f(x,y)$, is used to be the mass of the point (x,y). The centroid (x_c, y_c) of S can be defined as [9]

$$(x_c, y_c) = (\frac{m_{10}}{m_{00}}, \frac{m_{01}}{m_{00}}), \quad (9)$$

where m_{pq} is the (p,q) moment of S [10],

$$m_{pq} = \sum_x \sum_y x^p y^q f(x,y). \quad (10)$$

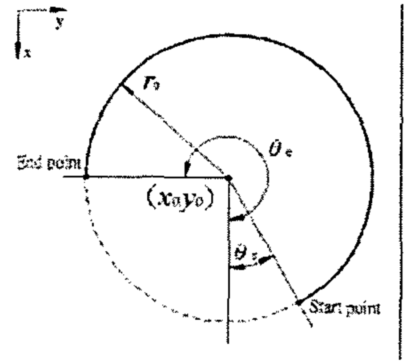


Figure 2: The parameters of a circular arc.

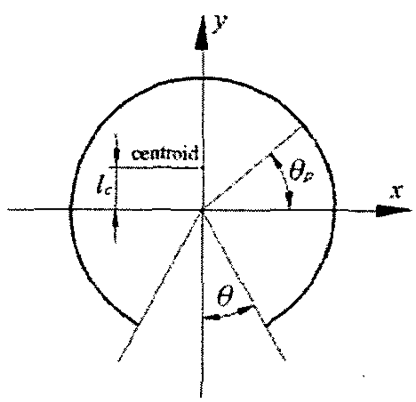


Figure 3: A circular arc that is symmetric about the y-axis. θ is the angle from the y-axis to the end point of the arc, θ_p is the angle from the x-axis to the point of arc, and the distance from the origin to the centroid is denoted as l_c.

It is easy to see that the centroid of a circular arc and the center of the circle (the arc lies upon) are on the symmetry axis of the arc. Without loss of generality, we let a circular arc be symmetric about the y-axis, the arc's centroid lie on the y-axis, and the center be at the origin (as shown in Fig.3). r_0 is the radius, θ is the angle from the y-axis to the end point of the arc, and θ_p is the angle from the x-axis to the point of arc. The ratio of the arc length to the complete circle is denoted as R_{ac}. The distance from the origin to the centroid is denoted as l_c, and

$$l_c = \frac{\sum(mass * y_i)}{\sum mass} = \frac{\int_{-(\frac{\pi}{2}-\theta)}^{\frac{3}{2}\pi-\theta} r_0 \sin\theta_p r_0 d\theta_p}{2\pi_0 R_{ac}}. \quad (11)$$

Since $0<R_{ac}<1$, we can get

$$\theta = \frac{2\pi - 2\pi R_{ac}}{2} = \pi - \pi R_{ac}. \quad (12)$$

With Eqs.(11) and (12), we can obtain the relation between l_c and R_{ac}:

$$l_c = \frac{r_0}{\pi R_{ac}} \sin(\pi R_{ac}). \quad (13)$$

When the arc is a complete circle, l_c equals zero. When the arc length is zero, l_c equals r_0. And l_c increases while R_{ac} decreases. The ideal arc length, L, can be obtained by

$$L = 2\pi \times r_0 \times R_{ac}. \quad (14)$$

Assume that there are m points in the set S, a circular arc can be verified while

$$\frac{m}{L} > R_T, \quad (15)$$

where R_T is a predefined threshold to decide if S is a real circular arc or not. The last two parameters, (θ_s) and (θ_e) can be obtained by

$$\theta_s = \tan^{-1}\left(\frac{x_c - x_0}{y_c - y_0}\right) - 2\pi \cdot R_{ac} \quad (16)$$

and

$$\theta_e = \theta_s + 2\pi \cdot R_{ac}. \quad (17)$$

2.3. Safety helmet detection

Since the contour of a safety helmet is a circular arc. With the proposed circle/circular arc detection method, we can find the position of helmets in the image. We use the simply geometric features to verify if any safety helmet exists in the circular arcs. In the real image (taken from the ATM's surveillance system), there are many small circles/circular arcs may be detected. In practice, since the position of the ATM user and the one of the camera are fixed, the size of the helmet in the image may be estimated, that is, the detected circular arc isn't a helmet if its radius is too small. We set a predefined size threshold, r_T. If a detected circular arc satisfy the condition,

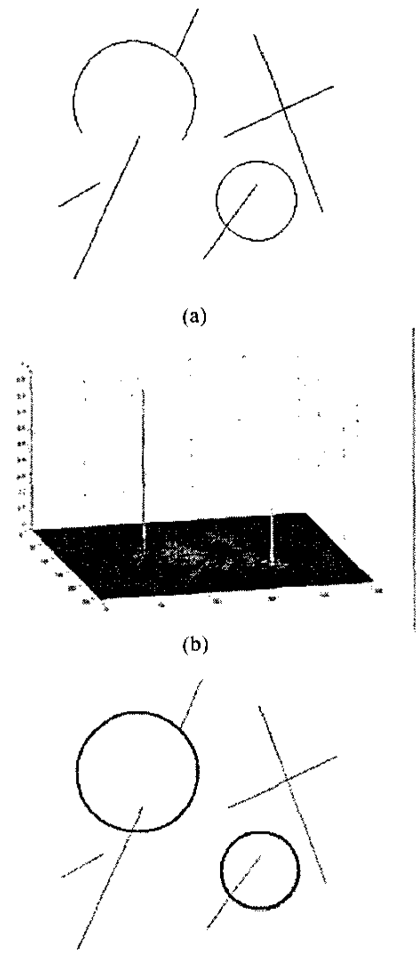
$$r_0 > r_T, \quad (18)$$

the circular arc is verified as the position of the helmet.

3. EXPERIMENTS

3.1. MHT for circle detection

Fig. 4(a) shows an image with a circle arc and a circle, where the image size is 256×256. We use the proposed MHT method to detect the circle/circular arc. When the voting process is finished, we use a voting space, $f_v(x,y)$, to see the voting results in the parameter space. The size of $f_v(x,y)$ is as the same as the one of the original image, and the initial values are set to be 0. For each member of the parameter space, we insert the value of the record accumulator, (x0, y0, r0), to $f_v(x_0, y_0)$, i.e., f_v records the voting results (edge points vote to the center of the circle candidate). If the value of $f_v(x_0, y_0)$ is over the threshold, the circle with the origin (x_0, y_0) may exist. The voting result (f_v) of Fig. 4(a) is shown as Fig. 4(b), the value of f_v is normalized. The circle detection result is shown as Fig. 4(c).



(a)

(b)

(c)

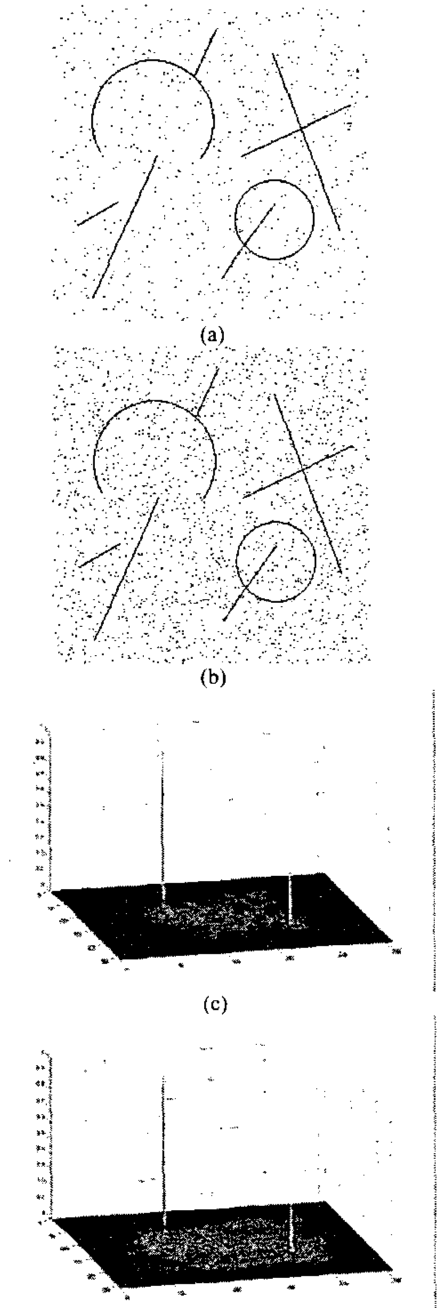
Figure 4: An example for the circle/circular arc detection: (a) the original edge image; (b) the voting result; (c) the detection result.

3.2. Circular arc detection under noise

In Fig. (5), we add 3% and 5% pepper noise to Fig.4 (a), and they are shown in Fig. 5(a) and Fig. 5(b), respectively. We use the proposed MHT method to detect the circle/circular arc. The voting results (f_v) are shown in Fig. 5(c) and Fig. 5(d), respectively. The circular arc detection results (R_T =0.8) are shown in Fig. 5(e) and Fig. 5(f), respectively.

3.3. Helmet detection

Fig. 6(a) is a real image taken from the ATM's surveillance system. Fig. 6(b) shows the edge image of Fig. 6(a). The circular arc detection result is shown in Fig.6 (c). The helmet is detected with r_T=20 and the result is shown in Fig. 6(d).



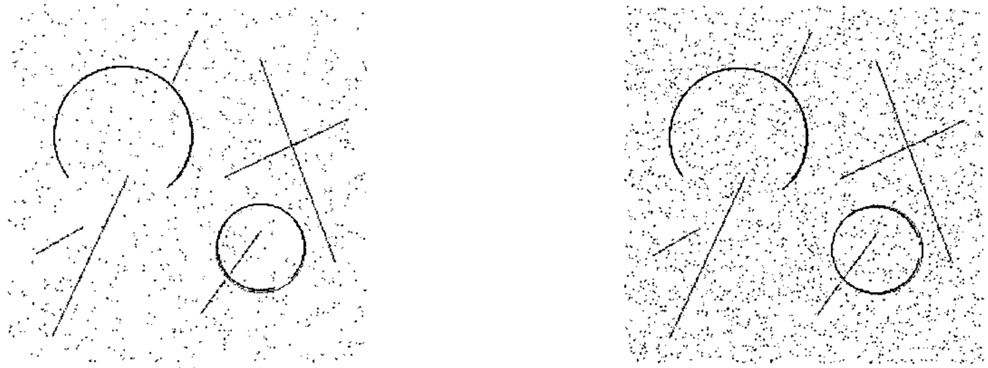
(a)

(b)

(c)

(d)

Figure 5: Examples for the circle/circular arc detection with noise: (a) the original noisy image, the Fig. 4(a) image with 1% noise; (b) the original noisy image, the Fig. 4(a) image with 3% noise; (c) and (d) are the voting results ofr (a) and (b), respectively.



(e) (f)

Figure 5 (continue): (e) and (f) are the circular arc detection results of (a) and (b), respectively.

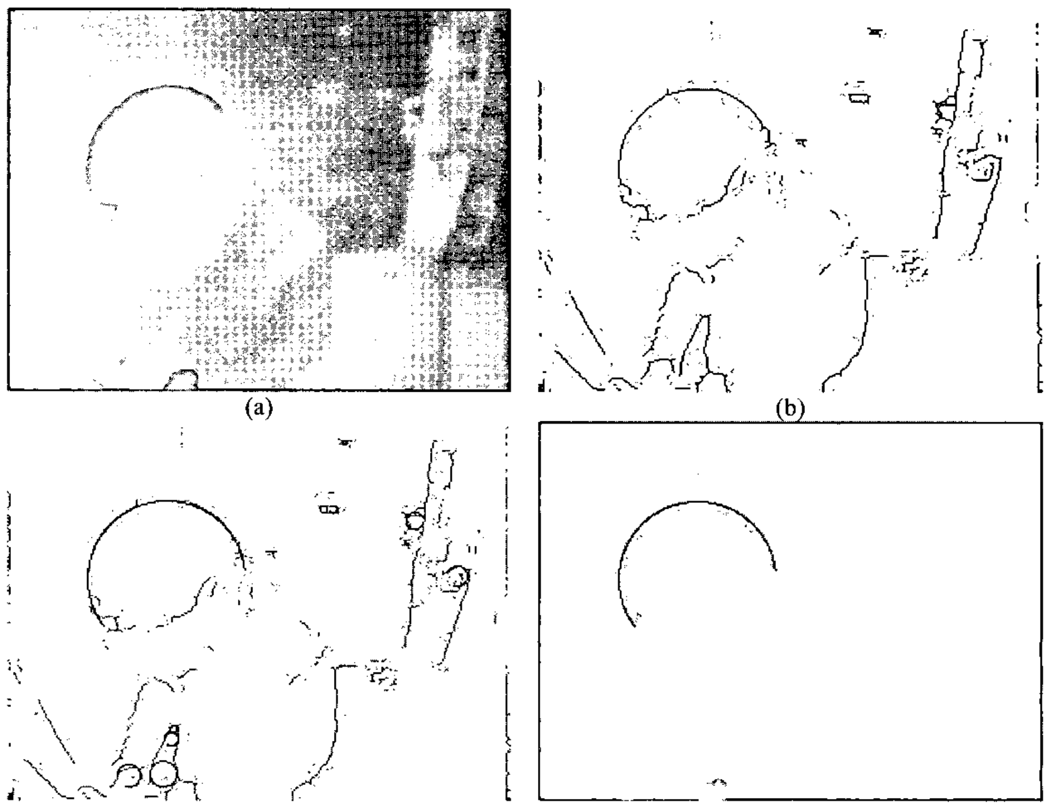


Figure 6: A real ATM image for helmet detection: (a) the original image; (b) the edge image of (a); (c) the circular arc detection result; (d) the helmet detection result.

4. CONCLUSIONS

In this paper, we propose a circle/circular arc detection method based upon the modified Hough transform. We can use the centroid information to compute the parameters of a circular arc. With the proposed method, we can detect the safety helmet for the surveillance system of the ATM. The proposed method can be applied to the surveillance systems of ATM's and banks, and it can provide the early warning to save-guards when any "customer" tries to hide his/her face information from surveillance, such as withdrawing money with the safety helmet. That will make the surveillance system more useful.

5. ACKNOWLEDGEMENTS

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