A New Fast Adopted Image Matching Approach with Arbitrary Rotation

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***Abstract*— To keep image matching method being self-adjusted is very difficult. As an important aspect of self-adjusted problem, the angle between template and image directly decide whether the matching could be success. Particularly, the result of image matching is seldom accurate when the traditional matching approach is used. In recent years, with series of new idea created, there is a great breakthrough in field of Image matching. A new self-adjusted image matching approach based on Pyramid model and polar coordinate is discussed in this paper. Polar coordinate is used to remove the implication of rotation and Pyramid model is taken to keep the real-time of algorithm. The simulation result shows that this algorithm is more stable and faster than the traditional pixel-to-pixel algorithm. Moreover, this approach is easier to carry out and become a simple step of complex analyzing system.**

Key Words: Image matching, Arbitrary Rotation, Polar Coordinate, Pyramid Model

I. INTRODUCTION

This paper draws attention to the cigarette identification. With the enhancement of faking capacity, people find it hard to identify the real cigarette by their eyes. A difficulty is found out that image of cigarette is covered with colorful information.

Because of increasingly comparability between the real cigarette and fake cigarette, these color information can't be always treated as a useful trait, as Fig. 1 shows.

(a) Real Package Image (b) Fake Package Image
Fig. 1 Comparison between real and fake package images

To solve this problem, image matching is applied in paper. Image matching is the approach that several images caught from the same scene in different time compare each other to find the same part. As a part of Image recognition, image matching can be adopted in wide range of area, such as commodity identification and face recognition.

There are two main directions in image matching:

1. Based on the pixel-to-pixel gray-related approach between template and image.
2. Basing on extracting the typical, common trait from the image.[5-10]

Taking consideration of cigarette identification, the new approach uses pixel-to-pixel and gray-related approach for arbitrary rotation that trying to decrease influence of color and noise.

This paper tries to find a solution about the difficulty that image matching is affected by the rotation and try to accelerate the algorithm at the same time. The purpose of approach is reducing the size of image to improve the speed of algorithm, and making full use of polar coordinate to enhance accuracy at the same time.

II. CHALLENGE IN ROTATED IMAGE RESEARCH

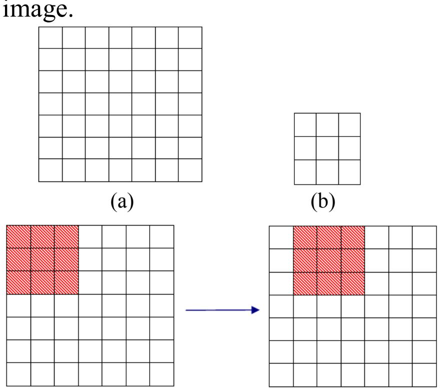
Before introducing the difficulty [1-10], the basic information should be discussed at the first.

Pixel-to-pixel gray-related approach is a basic way that it is just used like a mask-operator. Template slides on the image and comparability is calculated between template and the part of image that it is covered by template, as showing in fig.2.c.

The result of calculation represents the difference between image and template. This difference denotes as the correlation (1).

$$R(i,j)=\frac{\sum_{m=0}^{M}\sum_{n=0}^{M}[S^{i,j}(m,n)\times T(m,n)]}{\sqrt{\sum_{m=0}^{M}\sum_{n=0}^{M}[S^{i,j}(m,n)]^2}\sqrt{\sum_{m=0}^{M}\sum_{n=0}^{M}[T(m,n)]^2}} \quad (1)$$

When template T slides on the image S, the area covered by the template is also named as $S^{i,j}$ and (i,j) is the referenced pixel in the image.



(a) (b)

(c)

(a) Original image S (b) Template T
(c) Illustration of approach
Fig. 2 Pixel-to-pixel gray-related Approach

At first, it is easy to come up with how result of Image matching could be translated to the deduction between $S^{i,j}$ and T (2).

$$D(i,j)=\sum_{m=1}^{M}\sum_{n=1}^{M}[s^{i,j}(m,n)-T(m,n)]^2 \qquad (2)$$

To reducing the complexity of calculation, (2) is rewritten.

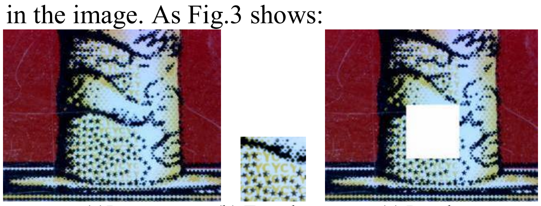
$$D(i,j)=\sum_{m=1}^{M}\sum_{n=1}^{M}[s^{i,j}(m,n)]^2+2\sum_{m=1}^{M}\sum_{n=1}^{M}[s^{i,j}(m,n)\times T(m,n)]+\sum_{m=1}^{M}\sum_{n=1}^{M}[T(m,n)]^2 \qquad (3)$$

Correlation (4) is extracted from (3).

$$R(i,j)=\sum_{m=1}^{M}\sum_{n=1}^{M}[s^{i,j}(m,n)\times T(m,n)] \qquad (4)$$

In terms of (4), the Correlation ranges from 0 to 1.

When the interaction-angle between template and image is less than 10 degrees, area which template depicts can be found in the image. As Fig.3 shows:



(a)Image (b) Template (c) Result

Fig. 3 Presentation of Pixel-to-pixel gray-related Approach

But if interaction-angle were over 10 degrees, image matching would not be success. The reason is that template is a matrix. Gray-level's array follows the matrix's rule. When the same graphics circumvolve some degree, the matrix must change at the same time. For example, if a horizontal line circumvolved some degrees at the range of 90, it would become a diagonal. It is same thing happen in the matrix represents the horizontal line. As Fig. 4 shows:

0	0	0	0	0	0	0	1
0	0	0	0	0	0	1	0
0	0	0	0	0	1	0	0
1	1	1	1	1	0	0	0

(a) Horizontal Line (b) Diagonal Line

Fig. 4 Difference of matrix between horizontal line and diagonal line ('1' represents black pixel, '0' represents white pixel)

Farhan Ullah[1] presented a approach that introduces the orientation code. This approach does make some breakthrough. But Orientation code only run fast by its transcendental rotated angle. Before algorithm processing, the system should know the exactly rotated angle at first. If there were no way to get the angle, algorithm would try all possible angles (0~360 degree) to rotate the template and match with the image. It will get the result after taking great much time to calculate.

Based on orientation code, Wang Jing-dong, Xu Yi-bin and Shen Chun-lin [2] put forward a new idea. This idea uses polar coordinate and circular projection into Image matching. This idea has found circular projection that isn't affected by the rotated angle. In the other word, circular projection doesn't change in the circumstance of arbitrary rotation of same image's. In this way, algorithm doesn't need the transcendental rotated angle like orientation code.

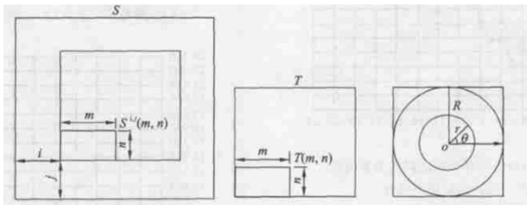
Paper takes advantage of this idea. But this idea hardly use in cigarette identification. Because of cigarette's high resolution photo, as Farhan Ullah's[1] arithmetic, Wang's algorithm don't run fast. Based on circular projection, *Pyramid Model* is added to algorithm.

III. THEORY OF CIRCULAR PROJECTION

In Cartesian coordinate system, position of one pixel in image is represented by Y-axis and X-axis. Once the image rotated around its center pixel, pixel's ordinate and abscissa would change, except for the center pixel. If ordinate and abscissa had been changed, gray-level's frame in the image would also change. As the result, both of using Image matching directly and after the Y-axis or X-axis projection can not be success.

Comparing with Cartesian coordinate system, polar coordinate system can hold a better rational invariance. Although phase is changed, radius component doesn't be affected by the rotation of image.

Therefore, template can convert from Cartesian coordinate system to the polar coordinate system. With template sliding on the image, $s^{i,j}$ changes to the polar coordinate system at the same time. Then circular projection is adapted to $s^{i,j}$ and template.



(a) (b) (c)

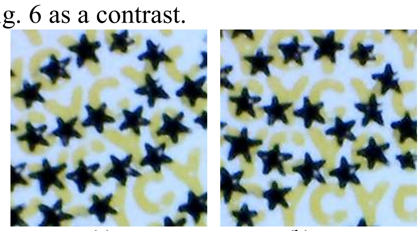
(a) Image S matrix in Cartesian coordinate system

(b) Template T matrix in Cartesian coordinate system

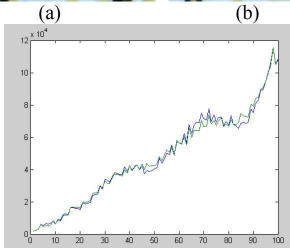
(c) Template, $S^{i,j}$ matrix in polar coordinate

Fig. 5 Relationship between Cartesian coordinate and Polar Coordinate[2]

To demonstrate circular projection is useful to image, paper shows the Fig. 6 as a contrast.



(a) (b)



(c)

(a) Original template (b) Rotated template

(c) Aggregative circular projection result between fore-and-after template

Fig. 6 Gray-level Projection

In circular projection, algorithm finds the same radius' pixels and sums their gray-level. In front of algorithm, radius ranges from 0 to template's inscribed circle's radius(R).

Variable of (1) is changed from (m,n) to r . As Equation (5) informed:

$$R(r)=\frac{\sum_{r=0}^{R}[S^{i,j}(r)\times T(r)]}{\sqrt{\sum_{r=0}^{R}[S^{i,j}(r)]^2}\sqrt{\sum_{r=0}^{R}[T(r)]^2} \quad (5)$$

IV. PYRAMID MODEL

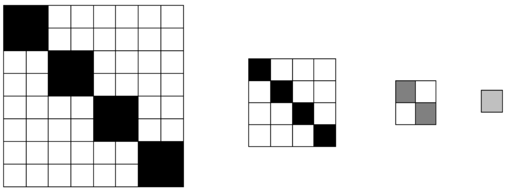
In Part III, it's obvious that circular projection approach does help image matching overcoming the difficulty of rotated image matching. But there are still some small problems in its application. In cigarette identification, circular projection algorithm cannot meet the need of real-time. During the analysis, the problem focuses on the conversion from Cartesian coordinate system to polar coordinate system. This action spends much time because it needs several square and rooting calculations. Besides, once template had slid, conversion would have to deal with the new-created object ($S^{i,j}$).

To deal with this problem, Pyramid Model is put forward. Pyramid Model is an image compression approach like a simple SWT. Original image is the largest layer, just like the Pyramid's foundation.

The compressed rule is: the gray-level of one pixel (i,j) in next layer is decided by average of four pixels' gray-level in the former one.

$$\{(2*i,2*j)(2*i-1,2*j)(2*i,2*j-1)(2*i-1,2*j-1)\}$$

In this way, when layer's serial number becomes higher, pixel's number in layer is less, just like a heaping Pyramid.



(a) Basic layer (8*8 pixels) Original image
(b) Second layer Result (4*4 pixels)
(c) Third layer Result (2*2 pixels)
(d) Top layer Result (1*1 pixel)
Fig. 7 Description of Pyramid Model

V. NEW IMAGE MATCHING METHOD

For speeding the circular projection, algorithm adopts the Pyramid Model to both template and image from the beginning. When compressed small enough, compressed template and image are conveyed to the part of circular projection to finish the Image matching.

Through the simulation, it is found that the algorithm lacks some degree of precision. The reason focuses on the correlation. Because the result of (5) is total near to (1). It brings a difficulty to sure the threshold.

Therefore, algorithm uses the Similarity Sequential Detection Algorithm [4] (SSDA). The main idea of SSDA is:

(1) Calculating and summing subtraction between $S^{i,j}$ and T (template);

(2) If difference is over the threshold, Calculating will terminate and turn to next Image matching between $S^{i,j}$ and T.

$$m_{i,j}=\sum_{r=0}^{R}\left|S^{i,j}(r)-t(r)\right| \quad (6)$$

Comparing with the (5), $m_{i,j}$, as a threshold, is easy to set during the simulation.

Fig. 8 shows flow chart of this approach.

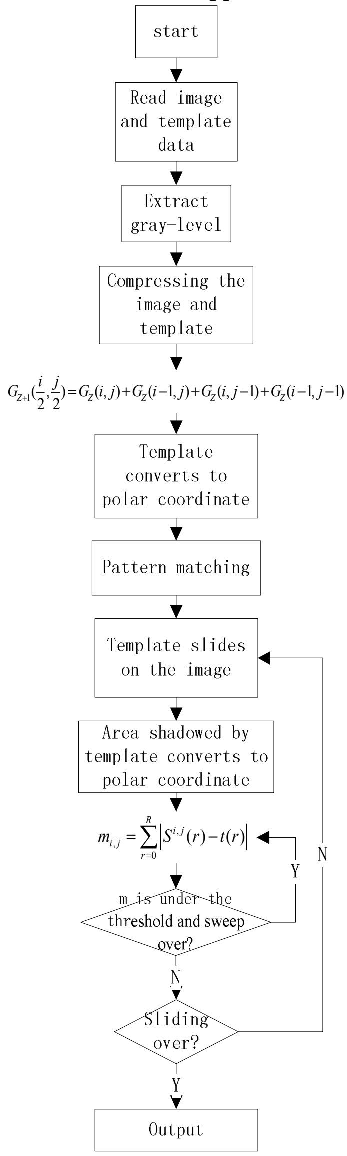


Fig. 8 Flow Chart

VI. SIMULATION

Linking to cigarette identification, cigarette named ZhongHua is chosen to be the example. 200 ZhongHua's package images rotated randomly is made up of testing database.

As the shows in Fig. 7, these high resolution photos are taken by pinhole camera, and they maybe the real or fake one.

Algorithm needs to pick the area is the most similar to template in the photos or directly identifies photos.

(a) Normal Image (b) Rotated Image

Fig. 9 Presentation of Image Source

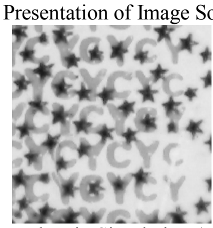
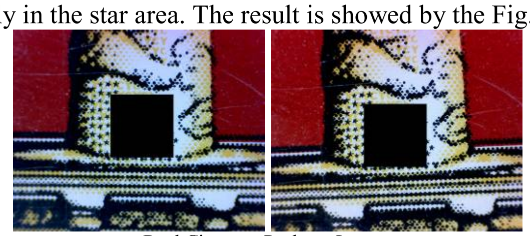


Fig. 10 Template in Simulation (star area)

The star area is pointed to be template. Based on eyes' identification, fake ZhongHua cigarette is prone to printing cursorily in the star area. The result is showed by the Fig. 11.



Real Cigarette Package Images

Fake Cigarette Package Images

Fig.11. Simulation Result

Because of importance of result, illustration is necessary based on result. Firstly, the black square appearing in real cigarette package image means image matching is successfully finished. The content in black square is sent to analysis in the following step. Otherwise, the result would show the whole cigarette package image without black square and acquire the conclusion that cigarette is fake.

In performance of identification accuracy, by using different idea of image matching, this algorithm is divided into type I that uses the idea of correlation and II contains SSDA algorithm in simulation. As a whole, new algorithm can identify correctly all the real cigarette photos and 80% the fake cigarette photos. Taking consideration of the area indeed be matched, algorithm can be success. In terms of performance of identification timely, because of high resolution photo, new algorithm can run at most 500ms, it could meet the need of cigarette photos' identification.

As showing in Table 1, the previous method from context can not be adopted in this method because the source images contain high resolution. Therefore, both of their application can not get a result. In comparison between algorithm I and II, by using a proper threshold in SSDA, new algorithm II holds higher accuracy and costs less time than algorithm I. As the result, the adoption of algorithm II that is put forward in this paper can be demonstrated in simulation part.

Table 1. Various Approaches Comparison Result in Accuracy and Time

	orientation code	circular projection	new algorithm I	new algorithm II
Accuracy (%)	/	/	72	95.1
Spend time (ms)	∞	∞	500	200

VII. Conclusions

A new approach is proposed for solving the problem of cigarette identification in Arbitrary Rotation by using circular projection, Pyramid Model and SSDA. This approach is quite different from the other approaches by using image compression to adjust the high-resolution photos. In this paper, algorithm uses the circular projection and polar coordinate system replaces the Cartesian coordinate system, Pyramid Model to compress the image and template, and SSDA to speed process of judgment and enhance the accuracy.

Based on image database, a satisfying result had been attained. The accuracy of algorithm is over 90% in simulation. And the proposed approach also takes less time for calculating algorithm.

References

[1] Ullah F, Kaneko S., Using orientation codes for rotation-invariant template matching [J]. Pattern Recognition, 2004, 37(2): 201-209.

[2] WANG Jing-dong, XU Yi-bin, SHEN Chun-lin, New Scene Matching Method for Arbitrary Rotation Journal of Nanjing University of Aeronautics & Astronautics Vol.37 2005.02: 6-10.

[3] Jeon B H, Lee S U, Lee K M. Rotation invariant Face detection using a model-based clustering algorithm [J]. IEEE Int Conf Multimedia and Expo, 2000.2: 1149-1152.

[4] Sun Chang-ming, Fast algorithm for local statistics calculation for N-dimensional images[J]. Real-Time Imaging, 2001, 7(6): 519-527.

[5] Dou Jianfang, Li Jianxun, Robust Image Matching Based on Rotation and Scale Invariant Shape Context ,2012 International Workshop on Image Processing and Optical Engineering,2012.01, Proc. of SPIE Vol. 8335.

[6] ZENG Luan, XIONG Wei, ZHAI You, Gun Bore Flaw Image Matching Based on Improved SIFT Descriptor, Eighth International Symposium on Precision Engineering Measurement and Instrumentation,2013.01, Proc. of SPIE Vol. 8759, 875912.

[7] Shi Jinglun, Chen Feng, Lu Jingbiao, Chen Gang, An evolutionary image matching approach,Applied Soft Computing 13 (2013) 3060–3065

[8] Liang Jianning, Liao Zhenmei, Yang Su, Wang Yuanyuan, Image matching based on orientation–magnitude histograms and global consistency, Pattern Recognition45(2012)3825–3833

[9] Chen Fang, Shi Jinfei, A New Method for Image Matching,2012 19th International Conference on Mechatronics and Machine Vision in Practice (M2VIP), 28-30th Nov 2012, Auckland, New-Zealand

[10] Guan Liming, Yang Qiankai, Lin Jian, 2-D image matching based on global harmony search optimization, International Conference on Measurement, Instrumentation and Automation (ICMIA 2012), 2013