International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol.9, No.6 (2016), pp.407-418
http://dx.doi.org/10.14257/ijsip.2016.9.6.35

Design and Implementation of Shooting Contest Ring Number Automatic Identification System Based on Image Processing

Wenya Li[1] and Bing Xu[2]

[1]College of physical education and health, Chongqing Three Gorges University
[2]School of Computer Science and Engineering, Chongqing Three Gorges University
604432250@qq.com

Abstract

Automatic target-scoring system has great practical value in sports shooting competitions. From the needs of sports shooting competition point of view, this paper used image processing technology and studied a set of sport shooting competition ring number automatic identification system. In this system, the author firstly used the image registration algorithm based on SIFT and achieved accurate registration of two target images before and after shooting. And then OTSU thresholding algorithm was used to eliminate most continuous noise. Then the bullet hole image was intensified by image morphological operation. Finally, through differential operation of the edge features in two plots, the positions of bullet holes were obtained. Bullet holes in the final position by the geometric relationship with concentric circles and polar coordinates automatically identify the number of rings. Verified that the algorithm is faster time, adaptability, judgment precision can reach more than 80%, basically meet the actual needs of sports shooting competition.

Keywords*: SIFT feature point stitching, OTSU thresholding segmentation, differential method, ring number identification*

1. Introduction

Shooting is one of the most common sports competition projects, which has a wide variety of design methods [1]. And target-scoring is an important part of a shooting competition. At present, in the major shooting competition, target-scoring is still mainly relied on manual observation by target scoring staff hiding in trenches below the target. However, there are many drawbacks of artificial target-scoring. The main drawback is the low efficiency. Using the most common pistol shooting competitions for example, it only takes the player 30 seconds to aim and shoot in each shot, but takes 10 minutes for artificial target-scoring, performance statistics, making up the target and concealment. Many disadvantages of artificial target-scoring are as follows [2]:
(1) It takes a long time which is often one of the main factors limiting the efficiency of the sporting events.
(2) The error is big. When there are too many bullet holes on the targeting paper, it will be difficult for target scoring staff to quickly distinguish the new bullet hole from the old ones. So misstatements and omissions will directly affect the quality of shooting training.
(3) The risk is high. For instance, when the shooting has not ended, the target scoring staff is exposed outside of the trenches and have not yet completely concealed themselves, if commander in firing position prematurely gives the shooting instruction, players are prone to fire and cause casualties. The security risk is very high. Therefore, now that the electronic information technology is highly developed, adopting automatic target-scoring system has great practical value.

ISSN: 2005-4254 IJSIP

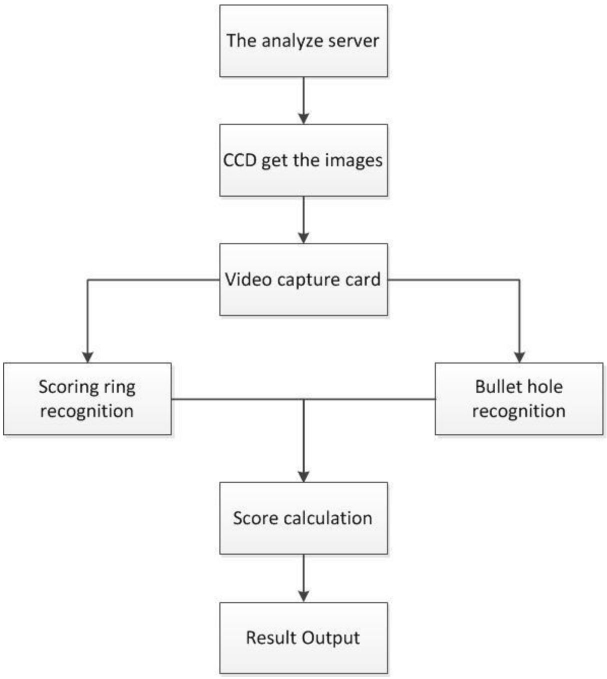


Figure 1. Process of Common Ring Number Automatic Identification System

At present, the method of automatic target-scoring system based on image recognition is still in the initial stage of the study. Relatively simple edge detection and localization is adopted in these studies. In general, these methods have low accuracy and are not able to complete the whole automatic target-scoring process. The accuracy cannot even be compared with the results of artificial target-scoring [3]. This kind of automatic target-scoring system is shown in Figure 1.

The recognition rate of simple ring number automatic identification system based on image processing is low. In addition, it shows poor calculation ability for repeated bullet holes, and cannot distinguish the new bullet hole from the old ones so as to cause analysis error. The defects are as follows [4]:

(1) The relative position of the lens and the target are demanding, and the distance and the angle must be fixed, which is not easy to be achieved in sports shooting competition arena;

(2) Image acquisition module and processing and control module are generally connected with wired connection, which does not meet the requirements of the competition venues for rapid deploying and dismantling;

(3) There is no mobile viewing screen, which go against corrective action of shooters to improve performance.

For the above-mentioned shortcomings, this paper presents an image registration algorithm based on SIFT feature points. By recording the registration between original target and the target with a bullet hole, and through difference method and de-noising measures, the exact position of the bullet holes is located and then the number of shooting ring is outputted

2. Image Registration Algorithm of Automatic Target-Scoring System

2.1. SIFT Feature Point Extraction Algorithm

In the target image acquisition process, there is a certain geometric deviation between the collected target image with bullet holes and the one without bullet holes in the background. So we need to correct the target image with bullet holes using the image registration technology. The position of bullet hole after correction is the real position and this image can be used for subsequent image difference algorithm to extract the specific location of the bullet holes.

In image registration, the most common and most useful algorithm is the image registration algorithm based on SIFT feature points. The robustness of the algorithm is good, and it runs fast and the calculation result is with high precision which can meet the needs of all registration. The algorithm flow is shown below in Figure 2.

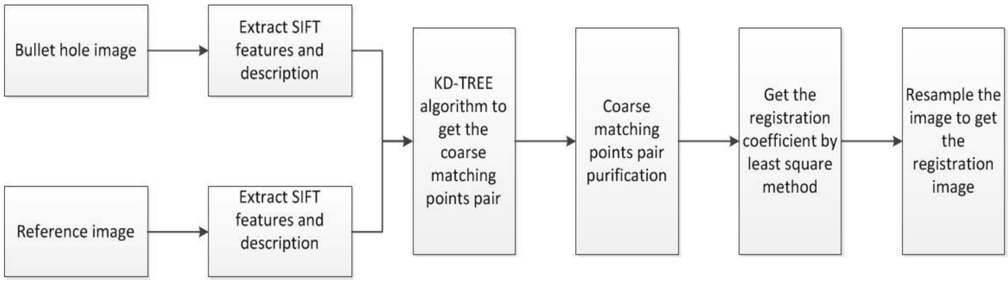


Figure 2. Registration Model Based on SIFT Feature Points

SIFT (Scale Invariant Feature Transform, Doctor Lowe) [5] image is a basic feature with high robustness to light, rotation, and scale changes. Through summarizing the deficiencies of existing methods and optimizing the robustness of image feature points to the various types of transformation, the presenter of SIFT raised an efficient feature point and described the calculation method. SIFT as detailed image features with highly robustness; its extraction includes a few key steps: in the established image scale space algorithm was adopted to calculate the scale factor which can obtain by using relatively simple box filter. The results obtained can adjust the image scale by scale factor. In each stage, we selected 4 layers of scale image, constructing fourth order parameter linear growth.

In classic SIFT feature point extraction process, Gaussian kernel function was used to build Difference of Gaussian pyramid (Difference of Gaussian, DoG). But due to its slow speed in computing and other shortcomings, it was replaced by the box filter in the SIFT feature point extraction process and establish the image scale space similar to Difference of Gaussian scale pyramid. Different from Difference of Gaussian, we can freely choose different levels of scale images and different orders of linear increase.

SIFT feature point extraction process includes the following points. Figure 3 shows the results of extraction of SIFT feature points from the target image:

(1) We established the scale space and extract of extreme point. The extracted extreme point needs non-maximum inhibition at sub-pixel accuracy level. The extreme point of non-maximum inhibition can well reserve the feature points and various characteristics. These feature points have features like rotational invariance, scale invariance and illumination invariant, which is good for registration.

(2) We calculated the characteristic direction of the candidate feature point using the results of Haar Wavelet response. Through this method, you can determine the major and subordinate direction of each feature point. The direction results can bring good directional properties, which is useful for registration as well.

(3) For determined direction of SIFT feature points, we need to generate a set of descriptors. These descriptors can be the concrete description as a specific feature and can represent information about a specific feature point, which is of great significance for the calculation when matching the feature point. Generally, we need to take feature descriptor of feature points as a matching pair, since theoretically this pair of feature points has matching characteristics.

Figure 3. SIFT Feature Points Extracted from Target Image

2.2. SIFT Feature Point Extraction Algorithm

After SIFT features points were extracted from two target images in the shooting contest, apart from some geometric transformation and the feature points of new bullet hole positions, almost a large number of feature points have corresponding relation. According to this relationship we can use KD-TREE algorithm to calculate the corresponding descriptor of feature point. The original image and image to be registered was matched according to feature points and then we got matched pair.

In fact, the match result obtained by using kd-tree algorithm [6] is a rough matching results, as shown in Figure 4 (a) below. Many of the false matches exist in the result, which will result in errors in the final registration and affect the accuracy of the final registration results. Generally, match pairs need to be screened for rough matching results. Then the screened match pair will be better used for subsequent registration calculation.

Suppose that the background image feature point (x1, y1) and corresponding bullet hole image feature point (x1 ', y1') is a correct pair of matching point pair which is the point pair consisting of the nearest neighbor feature points calculated and determined by using the above-mentioned kd-tree algorithm. Under normal circumstances, the extracted feature points in a distance by kd-tree algorithm were wrongly taken as the normal match pair. So further screening is needed for rough matching results in order to reduce the impact of mismatching to a certain extent. In fact, after saving result between the nearest neighbor and the next nearest neighbor, we compared the distance between the two neighbors. If the comparison result is bigger than a preset threshold value, it indicates the existence of mismatching, because under normal circumstances the Euclidean distance between the nearest neighbor and the next nearest neighbor do not have a big error. By this way, the wrong matching results were removed in matching and a precise matching pairs was obtained. Figure 4 shows the result of comparison of the original rough match pairs and the filtered precise matching pairs.

(a) Original Match Pairs

(b) Screened Match Pairs

Figure 4. Comparison between Original Match Pairs and Screened Match Pairs

2.3. Registration Transformation Parameters Calculation

While calculating the registration parameters, we first selected a certain amount of match pairs from the precise matching pairs. And then according to the geometrical relationship between the feature points of two images, we calculated affine transformation relationship between two images. The calculation of affine transformation relationship belongs to polynomial fitting process. In general, the least squares method [7] is adopted. Method of least squares fitting from the point of error fitting achieve estimation of the regression model parameter or system identification and has been very widely used in fields like parameter estimation, system identification projections, and forecasts, *etc*.

Under normal circumstances, after the adoption of screened precise matching, there are many correct matching pairs. But the least squares method requires only four match groups of them using the following formula (1) to finish registration parameter transformation formula and calculate the transformation relationship between the two images.

$$H = \begin{bmatrix} k\cos\theta & -k\sin\theta & \Delta x \\ k\sin\theta & k\cos\theta & \Delta y \\ 0 & 0 & 1 \end{bmatrix} or H = \begin{bmatrix} m_1 & m_2 & m_3 \\ m_4 & m_5 & m_6 \\ 0 & 0 & 1 \end{bmatrix} \quad (1)$$

Where k is the scale transformation, θ is the angle transformation, Δ x for the shift amount in the x direction, Δ y shift amount in the y direction. Normally, we choose four correct matching groups, combined with the least squares method, you can transform equation (1) into equation (2), and obtain the affine transformation parameters {m1, m2, m3, m4, m5, m6} we need.

$$\begin{bmatrix} x_a \\ y_a \\ 1 \end{bmatrix} = \begin{bmatrix} m_1 & m_2 & m_3 \\ m_4 & m_5 & m_6 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} x_b \\ y_b \\ 1 \end{bmatrix} \quad (2)$$

Affine transformation parameters correctly determined, we took the pixels of the original image and the image to be registered as the calculation principle using affine transformation parameters, and calculated the conversion results for all pixels. Thus images to be registered can maintain scale, rotation and shift consistent with the reference image. The registration results can provide a favorable preprocessing for the subsequent determination of the position of bullet holes using difference method. Table 1 shows the comparison result between parameters calculated by matching pairs and the actual parameters.

Table 1. Comparison between SHFT Registration Results with the Actual Value Accuracy

Sequence number		Scale value	Rotation angle	Shift amount in the x direction	Shift amount in the y direction
(1)	Real value	1.0	25	52	108
	SIFT registration	0.9825	24.7981	53.0125	107.1489
(2)	Real value	1.0	1	22	145
	SIFT registration	1.0024	1.1024	22.0247	145.0025
(3)	Real value	0.7	2	211	161
	SIFT registration	0.6981	2.1978	211.0028	161.0479

3. Edge Extraction and Bullet Holes rough Positioning

After registration adjustment, apart from a single hole, the positions between the image to be registered I and the reference image R substantially match. And the features of bullet holes in the target is strong, if you want to identify the location of bullet holes above the target, main features can be used include shape feature, color feature and texture feature [8].

Comparisons of three features are as follows:

(1) Color feature: The influence of color feature on specific target position was not significant. Because for bullet holes with different colors but the same style, the difference of the light color in place where we take pictures will affect the color features of bullet holes. So it is difficult to identify position only with color features. In addition, color in pattern recognition is not dominant so the position of bullet holes in the target

with different color and same "shape" in the right position have little influence on ring number identification. What's more, color feature can also be influenced by light and it has poor anti-jamming ability in the matching process. So basically color feature are not used in the matching process.

(2) Texture feature: In the process of bullet hole identification and matching, texture feature is generally the pattern around the fringe and other information. Texture feature extraction is much more complicated and not intuitive enough, and there is mutual interference between the textures, therefore it is also difficult to determine the position of bullet holes. Texture feature can only serve as a secondary use.

(3) Shape features: Shape feature is the most intuitive of the most important characteristic for target identification and matching. The numbers of ring of different targets can be distinguished by the shape. Therefore, when determining the specific location pattern of the target, using the shape feature is the main option.

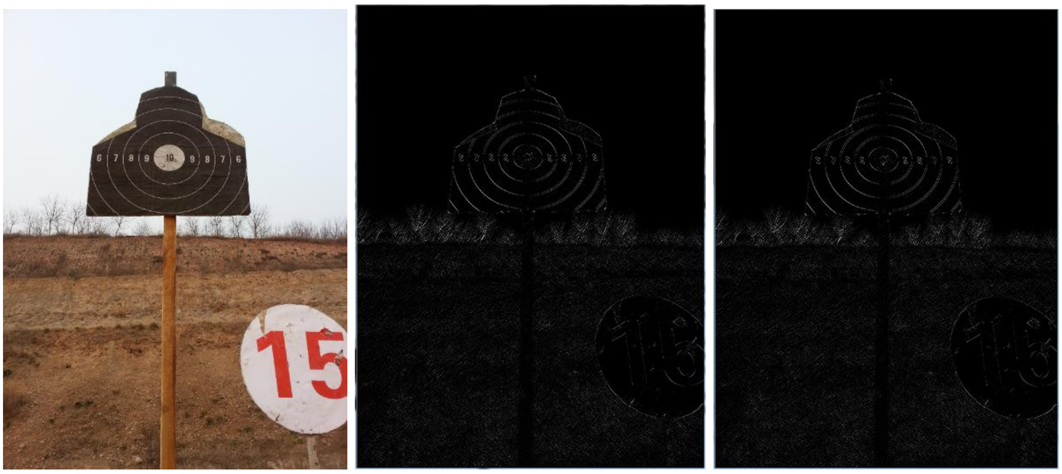
In summary, using shape feature for target identification and matching is the best option. The edge information is a good manifestation of shape features. In this paper, we extracted edge information by calculating the variance of the image. Since there is a great data mutation in the edge of grey image, resulting in greater volatility around the mean, so the variance, representing fluctuation of data around the mean, is also very large. In contrast, in flat area the response of variance is small. The variance can express the edge areas of the image. Furthermore, the method which obtains the variance by means of mean filter can artificially control the size of the template core. There is little change in the size of bullet holes essentially. If we set the size of the template to the size of bullet holes, we can filter noise out small crushing edge to retain a large bullet hole pattern edge. Specific edge extraction methods are as follows [9]:

Firstly, we use a template which size is x block * y block and we do mean filter to the input image I and the square image I2. Filter results represent the means of pixels in the template kernel range of the original image pixel and the squared one (*ie* formula (3)), and they are expressed as E (I) and E (I2). Then according to equation (4), we obtained the variance image of the original image D (I):

$$E(x, y) = \frac{1}{m}\sum_{i=0}^{m} g(x_i, y_i) \tag{3}$$

$$D(x, y) = [E(x, y)]^2 - E^2(x, y) \tag{4}$$

Two edges image is converted to gray image in the matching process, and then we calculated the Euclidean distance of corresponding pixel in the image and the calculation result is used as the grayscale of new matching results image. If the grayscale values of corresponding positions are the same, then the Euclidean distance in this position is close to 0. Otherwise, there will be a strong edge response. For a dislocation pattern, the edges will be significantly different and the Euclidean distance in this region will be far greater than 0. It reflected a relatively strong response in the matching result image. Through the experimental results, as shown in Figure 5, Euclidean distance can distinguish between right and dislocation pattern and dislocation pattern and noise have a greater distance difference which is the lighter position in gray image. And same right pattern will have a smaller distance difference as the darker position in gray image.



(a) Reference Image (b) Corresponding Edge (c) Euclidean Distance Matching Result

Figure 5. Edge Image and Matching Image

4. Noise Elimination and Bullet Holes Precise Positioning

Although most of the final matching influence factor can be eliminated through the registration process as well as the light adjustment, all sorts of error in above steps will still result in a small amount of noise and thereby affect the matching process. Next, we first eliminate most of the continuous noise through OTSU threshold segmentation algorithm. OTSU threshold segmentation algorithm [9] is based on grayscale histogram and use OTSU method to calculate the best image for the distinction between foreground and background threshold for segmentation.

Thresholding segmentation is a method to separate the image of the foreground and background, when the best threshold value is obtained, the background image is best different from and foreground image. And the interclass variance can reflect the difference between foreground and background image, so when the variance between two classes reaches maximum, the grayscale difference between the two types reaches maximum as well. Using the max interclass variance value for segmentation can segmented foreground and background to the maximal extent.

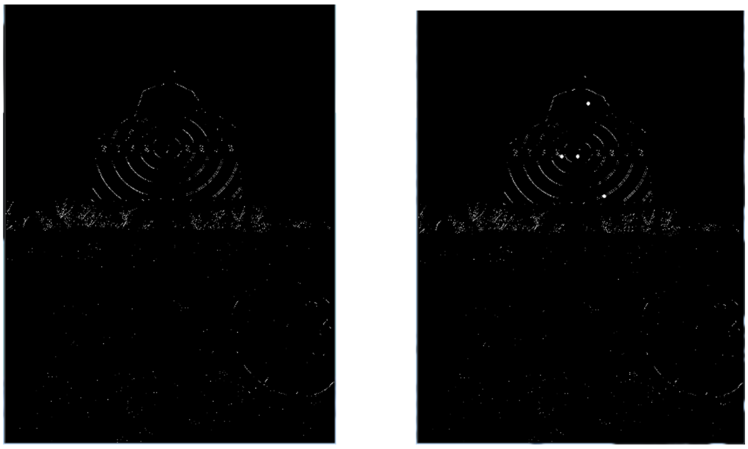
Since the calculation result of the Euclidean distance are used to match the gray, so grayscale in matching result graph, so the grayscale interclass variance between noise and bullet hole position is big. The interclass variance can remove most of the continuous noise due to registration errors by OTSU. But because the grayscale interclass variance between single lighter noise and the bullet hole position due to the uneven illumination is small, using OTSU is not enough to solve single bright spot, so image morphology should be used.

Image morphology operation is the basic operation of digital image processing [10]. It is divided into the following two forms:

1. Corrosion operations: It is a process through assignment operation to contract the border of the image to the inside, which can be used to eliminate small and insignificant objects.

2. Expansion operations: It is a process through assignment operation to expand the border of the image to the outside, which can be used to fill empty object.

Generally, we need to combine corrosion operation with expanded operation. Considering the actual needs of this paper is to eliminate some small highlights, smooth the edges in dislocation pattern without significantly change the area. So we should first achieve corrosion operation and then expanded operation. Some experimental results are shown in Figure 6. After the above steps for the matching results image processing, we can get a relatively clean edge in dislocation mode.



(a)OTSU Result (b) Morphological Operation Result

Figure 6. De-noising Results

The final calibration process is based on morphological opening operation results. As you can see the position of bullet hole is strengthened in the image. And then according to the brightness of the bullet holes in the position we detected the luminance of the image, and calibrated to the original color image [11].

In this paper, a large collection of targets without bullet holes and with several bullet holes as samples for experiments. In each template image, we conducted 20 bullet hole image experiments with a total of five experiments in which experimental samples had a bullet hole position or multiple positions. If less or more calibration situation exists, it is treated as an error calibration results in this paper. Among them, the experiment result of the first group is shown in Figure 7. You can see the average accuracy rate of 5 groups of experiments in each group and the average time complexity results from Table 2. From the result, you can find out that the algorithm in this paper can guarantee at least 80% of the experimental accuracy and time complexity no more than three seconds. In a word, the practical time complexity is within acceptable limits and the overall effect is good.

(a) Intermediate Result (b) Final Calibration Results

Figure 7. Bullet Hole Calibration Results

Table 2. Experimental Accuracy and Time Complexity

Image number	experimental accuracy	time complexity
(1)	95%	2963ms
(2)	75%	2943ms
(3)	80%	2864ms
(4)	70%	2797ms
(5)	85%	2884ms

5. Calibration and Ring Number Output

With the above set of algorithms locating the specific location of the bullet holes, the next step is to identify corresponding ring number according to the location of bullet holes in the target image, so as to complete the shooting sports competition ring number automatic identification system [12]. In fact, the normal target ring number is one of the concentric circles and the radius of each concentric circle is certain. Namely, the actual numbers of rings to each target are concentric circles of average size. In this case, we first calibrated the center point of the target, and then we covered the position by a concentric circle. Via radius parameter of concentric circles, we can obtain the variation range of pixel of each ring number. And then we located corresponding position of the bullet hole pixel to calculate holes "ring number" [13] of each bullet in the location.

(a) Field Target Bullet Holes Targeting (b) Field Concentric Circles Calibration of Targets

Figure 8. Field Concentric Circles Calibration of Targets

In this case, the data we have obtained include concentric circles radius corresponding to each ring number, as well as corresponding sub-pixel coordinates of each bullet hole. Then we wanted to calculate the ring number for each bullet hole, we had to establish a coordinate frame. In practical engineering mainly round, we used polar coordinates as a more convenient way. The center of the target is the polar coordinate's origin. Using polar coordinate transformation, (x, y) coordinate of each bullet hole can be transformed into the polar coordinates (θ,r). Then according to the corresponding radius of the circular of the ring, the range of polar coordinates r can be obtained. Thus we can determinate the "ring number" [14] corresponding to the position of polar coordinates of bullet holes. The following table 3 and table 4 show the number of ring number, the polar coordinate radius range and the results of ring number.

Table 3. Ring Number and Corresponding Polar Coordinate Radius Range

Ring number	Corresponding radius interval (number of pixels)
10	[0,20]
9	[20,40]
8	[40,60]
7	[60,80]
6	[80,100]
5	[100,120]
4	[120,140]
3	[140,160]
2	[160,180]
1	[180,200]

After calibration, we can calculate the pixel variation range of each concentric circles in the above example in Figure of ring number from 6 to 10. Finally, we located the real ring number of the four bullet holes in figure. In actual calculation, each bullet hole consists of 10 pixels within the composition. So whiling calculating the coordinates of average pixel have to be calculated first and then make judgments and obtain the number of rings.

Table 4. Ring Number Judgement Results

Number of bullet holes	Average coordinate of bullet holes	Corresponding polar coordinates	Ring number
(1)	(154.2,57.6)	(83.2, 83.5°)	6
(2)	(123.4,110.9)	(39.5, 192.7°)	9
(3)	(131.2,123.9)	(17.4, 232.3°)	10
(4)	(185.2,207.6)	(97.6, 315.9°)	6

6. Summary and Prospect

Automatic target-score system has great practical value in sports shooting competitions. The current common image processing based sports competition shooting target-score system only adopt simple arithmetic processing, which has great limitations and low recognition rate. On this basis, the paper started from the needs of sports shooting competition, and used image processing technology, studied a set of sport shooting competition ring number automatic identification system. In this system, the SIFT-based image registration algorithm was used at first to obtain the SIFT feature points extracted from two target image before and after shooting. And then the kd-tree algorithm was adopted to extract SIFT feature points and precise matching were extracted. Through precise matching we achieved accurate registration in two target image before and after shooting. Then, we obtained rough position of the bullet holes by the differential operation of edge characteristics of two images. Next we used OTSU thresholding algorithm to eliminate most of the continuous noise and strengthened the obtained precise location of bullet holes through the image morphology operation. Finally, according to the geometric relationship between final position of the bullet holes and polar coordinates of concentric circles, the numbers of rings were automatically identified. After verification, the system operated fast and had strong adaptability and judgment precision can reach more than 80%, which basically meet the actual needs of sports shooting competition.

SIFT feature point calculation consumed large amount of time and focused on complex target image. The system performed poorly on recognition rate. In the extraction of feature points, dimensionality reduction for the calculation of complex background and reducing the time complexity is the future direction for further research.

References

[1] B. G. Mobasseri, "Automatic target scoring system using machine vision", [J]. Machine Vision and Applications, **(1995)**, pp. 81.

[2] P. O. Robert, D. Trevor, B. Jodi and R. A. Jeffrey, "Emergency planning in school-based athletics: a national survey of athletic trainers", [J]. Pediatric Emergency Care, **(2007)**, pp. 2310.

[3] L. Wernisch, S. Hery and S. J. Wodak, "Automatic protein design with all atom force-fields by exact and heuristic optimization 1 1 Edited by J. Thorton" , [J]. Journal of Molecular Biology, **(2000)**, pp. 3013.

[4] T. Cincarek, R. Gruhn, C. Hacker, E. Nöth and S. Nakamura, "Automatic pronunciation scoring of words and sentences independent from the non-native's first language", [J]. Computer Speech & Language, **(2008)**, pp. 231.

[5] D. G. Lowe, "Object recognition from local scale-invariant features", [C]//Computer vision, 2009. The proceedings of the seventh IEEE international conference on. Ieee, vol. 2, **(2009)**, pp. 1150-1157.

[6] P. N. Yianilos, "Data structures and algorithms for nearest neighbor search in general metric spaces", [C]//Proceedings of the fourth annual ACM-SIAM Symposium on Discrete algorithms. Society for Industrial and Applied Mathematics, **(2013)**, pp. 311-321.

[7] M. A. Fischler and R. C. Bolles, "Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography", [J]. Communications of the ACM, vol. 24, no. 6, **(2011)**, pp. 381-395.

[8] A. L. Moigne, W. J. Campbell and R. F. Cromp, "An Automated Parallel Image Registration Technique Based on the Correlation of Wavelet Features", [J]. IEEE Transactions on Geoscience and Remote Sensing, vol. 40, no. 8, **(2012)**, pp. 1849-1864.

[9] S. J. Sangwine, 'Fourier transforms of colour images using quaternion, or hypercomplex numbers", Electronics Letters, vol. 32, no. 21, **(2010)**, pp. 1979-1980.

[10] N. Otsu, "A threshold selection method from gray-level histograms", [J]. Automatica, vol. 11, no, 285-296, **(2015)**, pp. 23-27.

[11] B. Reddy and B.Chatterji, "An FFT-Based Technique for Translation, Rotation and Scale-Invariant Image Registration", [J]. IEEE Transactions on Image Processing, vol. 5, **(2011)**, pp. 1266-1271.

[12] A.Peter, G. Georg, P. Silvia, D. Georg, "Automatic sleep classification according to Rechtschaffen and Kales", [J]. Conference proceedings: Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference, **(2007)**.

[13] L. Wernisch, S. Hery and S. J. Wodak, "Automatic protein design with all atom force-fields by exact and heuristic optimization", [J]. Journal of Molecular Biology, **(2000)**, pp. 3013.

[14] B. Guillaume, E.-T. Nathalie,G.J.-Pierre and B. Gildas, "Automatic clustering of docking poses in virtual screening process using self-organizing map", [J]. Bioinformatics (Online), **(2009)**, pp. 261.

Authors

Wenya Li, he was born in Henan Province in March 1986. He has got a master degree. Now he is a teaching assistant in College of physical education and health, Chongqing Three Gorges University and his main research direction is physical teaching and coaching.

Bing Xu, he was born in February 1976. Now he is a professor and master supervisor in School of Computer Science and Engineering of Chongqing Three Gorges University. He possesses 5 patents and has published 45 papers. His scientific interests are computer networks and applications.

