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Mesh belt with volleyball detection based on the improved Hough transform theory in the application of game scene analysis

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ABSTRACT

The continuous development of computer technology and internet technology promotes the improvement of analysis techniques on sports image and video files. In practical sport, being able to quickly extract useful information receives more and more coaches and sports researchers' attention, also in image analysis of volleyball, the demand is also growing day by day. In this paper, for the detection technology of mesh belt and volleyball in volleyball scene it conducts status analysis, first it introduces the application of the traditional Hough transform in mesh belt and volleyball detection, and then analyzes the shortcomings of traditional Hough transform algorithm and proposes improvement direction for the algorithm aiming at the defects of the characteristics, explores the improved linear transform and random Hough circle transform, and also explores the improved Hough circle transform algorithm combined with self-adaptive search algorithm, and analyzes the advantages and detection effects of the improved algorithm, provides a theoretical basis for the information detection technology of volleyball scene by the analysis process and research findings in the text.

Keywords: Hough transformation; threshold, random hough circle transformation, self-adaptive search algorithm.

INTRODUCTION

The technological development of volleyball is inseparable from the research of all scholars, also cannot be separated from the development of computer technology; computer technology with its unique high and strong computing power, makes the information analytical results of sports video and images made great improvement; in volleyball the detection technology with volleyball and mesh nets in volleyball scene helps to improve the analysis on the spiking and the padding technology[1]. For the improvement technology of image information detection algorithm and Hough transform many scholars have made their efforts, which has certain role on the development of sports image and video analysis techniques and the enhancement of volleyball technology; some domestic scholars have contributed some of his views and findings.

Wherein: Bo Chang-bing *et al* [2-4] proposed a method to detect circular PCB Mark by Hough transform, the detection image continues to the threshold transform, and use an area to segment, separated Mark region and the background from noise, calculated the center of Mark region, the accumulate range of the circle center for Hough transform was limited near this area; Tang Min, et al [5][6]on the basis of expectations on the samples number of smallest point set this criterion, compared the two methods of the random Hough transform and Tabu search algorithm, obtained that the Hough transform is usually superior to the Tabu search, from the simulation and experiment of actual images, when the extracted primitive correct rate is the same the random Hough transform is 1-2 times faster than Tabu algorithm; Zhou Feng *et al* [7], calculation and analysis of image detection in steel storage site demonstrated that random Hough transform algorithm can accurately position on the steel pipe and identify number in higher interference, and mutual shielded steel pipe can be accurately identified too.

Based on previous studies this paper conducts research on the detection technology of mesh belt and volleyball in volleyball scene, analyzes the application of traditional Hough transform algorithm and improved Hough transform algorithm in the mesh belt and volleyball detection, in order to provide a theoretical basis and development detection for volleyball scene detection technology by the algorithm research.

2. THE APPLIED THEORY OF TRADITIONAL HOUGH TRANSFORM IN MESH BELT AND VOLLEYBALL DETECTION

In volleyball match mesh belt and volleyball are both very important information; there are eight camera positions in volleyball venue, you can the extracted location information of the mesh belt to determine the location of the camera shooting; in the database of volleyball image, when there is a close-up information on the volleyball it is often the volleyball players' spiking or padding the ball exciting action, so long as we know the contour information of the volleyball we can know the size of the volleyball; the Hough transform discussed in the paper is used to find the mesh belt and volleyball, which can map the feature points of the image to the parameter space, and obtain the relationship between the image feature points[8]. Hough transform can detect the shape of a target, and the noise is less affected by the curve intermittent, which has a strong anti-interference. In this study, it analyzes the linear transform and circular transform of Hough changes, proposes the defects of the traditional transform, and provides guidance directions for improving the Hough transform.

2.1. Straight line of the traditional Hough transform

Hough straight line is the basis of the Hough transform; for a straight line and a point (x_i, y_i) on the straight line as shown in the linear equation (1), there are myriad straight lines through the point, and these straight lines are intersected at this point; in the formula (1) different a, b corresponds to different linear equations, and therefore formula (1) can be rewritten as the equation parameters shown in the form of formula (2).

$$y_i = ax_i + b \tag{1}$$

$$b = -x_i a + y_i \tag{2}$$

For the linear equation with slope of a' and intercept of b', if two points $(x_i, y_i), (x_j, y_j)$ on the straight line are transformed to parameter equation, they must intersect in (a', b') of the parameter space, and the image condition of the $x-y$ plane and the parameter plane is shown in Figure 1.

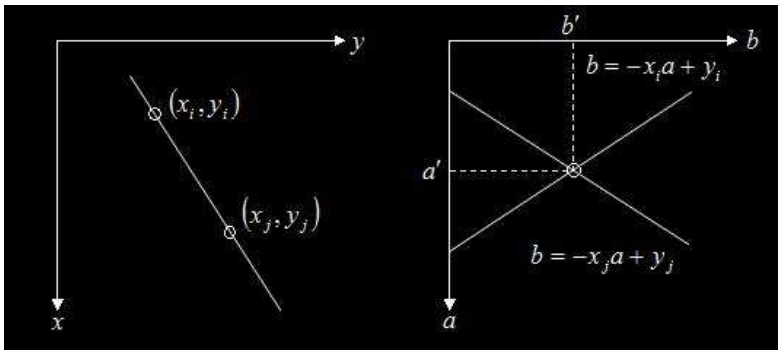

Figure 1: The relationship image of the point and straight line in the $x-y$ plane and the parameter plane

Figure 1 in the left shows a straight line image through the point $(x_i, y_i), (x_j, y_j)$ in the $x-y$ plane, the right figure represents the image that two straight lines intersect in point (a', b') in the parameter plane.

Hough transform can divide parameter space further into the accumulator unit as shown in Figure 2; in Figure 2 $(a_{\max}, a_{\min}), (b_{\max}, b_{\min})$ respectively represents the desired range of the slope and intercept values; For point (i, j) in the image calculate the equation parameters as shown in the formula (2), we can get one matrix on a, b, you can first substitute the formula (3) into equation (2) to get the corresponding value b.

$$a = a_{\min}, a = a_{\min} + 1, \cdots, a = a_{\max} \tag{3}$$

In the matrix b can take the approximate value; if the obtained solution is b_q for a value a_p, then set $A(p,q)$ satisfies the equation (4); In the last calculation process of the formula (4), the value Q of $A(i,j)$ is corresponding to the point Q on the straight line in the $x-y$ plane as shown in Formula (1), the number of segments in the plane determines the accuracy of these points' collinearity.

$$A(p,q) = A(p,q) + 1 \tag{4}$$

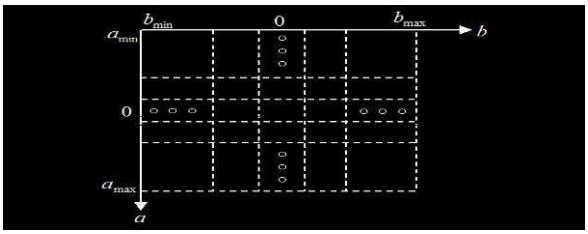

Figure 2: The further division schematic of parameters plane for Hough transform

2.2. Circle of the traditional Hough transform

The basic idea of Hough circle is to first map the point in the image to the parameter space, then put the center and radius corresponding to the parameter space into the accumulator, finally determine the circle according to the value of accumulator; for any point (x,y) in the image, if it is in the circle with the center of (a,b), and the radius of r, then the point satisfies the formula (5).

$$(x-a)^2 + (y-b)^2 = r^2 \tag{5}$$

For formula (5) it can be converted to the parameter equations about (a,b,r), as shown in formula (6) below.

$$\begin{cases} a = x - r\cos(\theta) \\ b = y - r\sin(\theta) \end{cases} \tag{6}$$

In Formula (6) $\theta \in [0,2\pi]$, for the Hough circular transform, the radius of the circle to be detected can be set as $r \in [R_1, R_2]$, and one point (x,y) in the image, then θ, r traverse $[0,2\pi]$ and $[R_1, R_2]$ by the step length of $\Delta\theta, \Delta r$, after traversing all points of the image, obtain the accumulator array A, wherein any one element $A(a,b,r)$ of the array represents radius r, the center of the circle is the accumulated value of (a,b); when the $A(a,b,r)$ is larger, it means the possibility of the existence of a circle with the center of (a,b) and radius of r is greater; meanwhile the physical meaning of the changes from the formula (5) to the formula (6) can be considered as in the image space a circle is corresponding to a three-dimensional upright cone in parameter space, as shown in Figure 3.

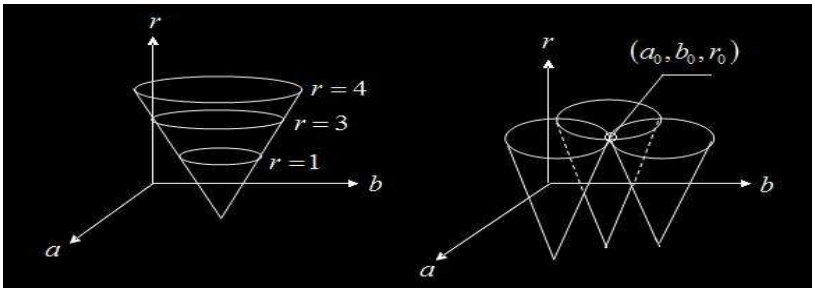

Figure 3: The schematic diagram of the circle and points on the circle in the parameter space

The circle of the three-dimensional upright cone image on the left of the figure 3 is mapped to the parameter space on the right, then form the equation about (a,b,r); If substitute the three points of the image into the parametric equations and in the premise that the parametric equations are solvable, in the parameter space the three upright cones certainly intersect at one point, points (a_0,b_0,r_0) are shown on the right in Figure 3.

2.3. The improvement direction of traditional Hough Transform

The traditional Hough line transform has significant flaws due to its large amount of calculation and the large space of calculation, etc. The traditional Hough transform uses method of exhaustion to transform every point in the image to the parameter space, and gets a range of (ρ,θ) values; and then solve the local maxima of (ρ,θ), but according to the actual situation of the mesh belt detection experiment, in the volleyball scene the mesh belt has the following three features:

A. Mesh belt is consisted of several straight lines, and it has certain height and length;

B. In the volleyball image mesh belt generally accounts for between a quarters to four-fifths of the total width;

C. In volleyball court the camera has a limited shoot angle.

Feature A shows that as long as a straight line can be detected, there is no need to use Hough transform exhaustive manner to traverse out all the line segment; Feature B indicates when the mesh belt width in the image is a quarters total of the total width, the most cases are due to the camera photographed parts of the mesh belt or the athlete keeps out parts of the mesh belt, and in volleyball scene in addition to mesh line there is no other straight lines that can account for a quarter of the total width of the image; so in the improvements of Hough line retrieval it should be noted that when the length of the line segment is higher than a set threshold it can be considered as a mesh belt; Feature C indicates that when the camera is directly facing the volleyball court, it cannot shoot the mesh belt, when the camera is directly facing the mesh belt the captured mesh belt is substantially parallel to the width direction of the image, when the camera is broadside on the mesh belt the shooting angle ranges 10° -30°.

In the traditional Hough circle transform for a given point on the image we need to use method of exhaustion to determine coordinate values of enormous center and radius, in view of this the calculation amount conventional circular Hough transform is huge; in order to avoid the defects of large amount of calculation caused by exhaustion, we can use the randomized Hough transform; random Hough circle transform is a multi-to-one mapping, that is to map the non-collinear scatter point randomly generated by the image space to a point in the parameter space, thus avoiding the one to many mapping in traditional Hough circular transform; in order to avoid the blindness caused by random Hough ideology, you can use the adaptive search method and color information characteristics of the image to improve the efficiency of the algorithm combining with random Hough circle changes.

3. APPLICATION OF IMPROVED HOUGH CHANGES IN THE MESH BELT AND VOLLEYBALL DETECTION

In view of the analysis in 2.3, this paper for the improvement direction of Hough transform, designs improved Hough straight line detection method and improved random Hough circle volleyball detection method.

3.1. Straight line of improved Hough Transform

When the camera is broadside on the mesh belt, the image captured is shown in Figure 4; the left and right figure in Figure 4 reflects two directions of the captures mesh belt; in analytic geometry the direction can be reflected by the slope, the left figure represents the case when the slope of the mesh belt is negative, the right figure represents the case when the slope of the mesh belt is positive; in the experiment for both directions we take a different algorithm to process; Since the mesh belt has a certain height, especially when the camera is facing in the side of the mesh belt they are all close-up scenes, the mesh belt height is much greater, so the straight line slope of the mesh belt detection is variable.

In Figure 5 the gray part is the mesh belt, straight line a and b are both mesh belt that can be detected, but the slope of the two straight lines are not equal; apparently straight line a is parallel to the mesh belt which is the best case, while straight line b has a certain angle with the mesh belt; according to the experiments, the straight line segment in the detection of the mesh belt is mainly to determine the position of the camera, it doesn't have exorbitant requirements for the angle of the straight line segment; so the value of angle θ can be intermittent, that is to regard

five degrees as step long and take {0○, 5○, ..., 30○}, values of angle θ have been greatly improved compared with the traditional Hough transform .

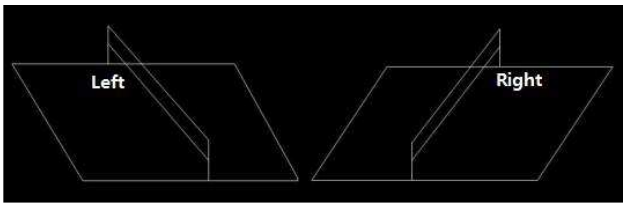

Figure 4: The schematic diagram of positive and negative performance of mesh belt's slope

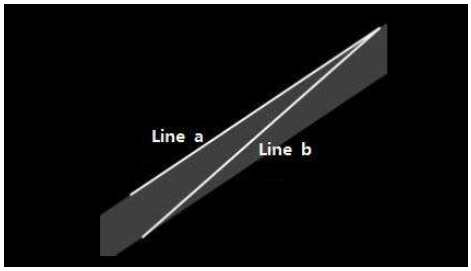

Figure 5: The condition of straight line segment detected in the belt

The algorithm of improved Hough line changes has the following four steps:
Step1 the case of infinite slope will not occur in the straight lines from detection to the mesh belt, so we follow the traditional linear equation of formula (7) below.

$$y = ax + b \tag{7}$$

Step2 set the image width as d , minimum length of the mesh belt's straight line is $d_{\min}$, (x', y') means one point of the image, and then from left to right, from the top to down traverse the image to find a straight line; thus it is divided into two cases, namely when the mesh belt is in the case of $x' < \frac{d}{2}$ as shown in the left of Figure 4 and the slope of the mesh belt is positive, the line can be detected; similarly when the mesh belt is in the case of $x' > \frac{d}{2}$ as shown in the right of Figure 4 and the slope of the mesh belt is negative, the line can be detected; take the left figure for an example $\left\{a = \tan 0^{\mathrm{O}}, a = \tan 5^{\mathrm{O}}, \cdots, a = \tan 30^{\mathrm{O}}\right\}$; and first fix the value of a and set it as a' , and increase x' in steps of 1; suppose the cumulative length is Δx and $\Delta x \le d_{\min}$, and the final value of x is $x'' = x' + \Delta x$, then the determining field Δx of y'' is relevant and the expression is in the formula (8) below.

$$y'' = \tan\theta \cdot \Delta x + y' = a' \cdot \Delta x + y' \tag{8}$$

Step3 to determine whether the point (x'', y'') on the image is white dots of the mesh belt, and if it is then it will be classified as a point on the straight line $y' = a'x' + b$; and here we need to set an accumulator and an interval point accumulator $interval\_sum$ to remember the number of points in the straight line $y' = a'x' + b$ on the image, $interval$ represent the maximum number of points not on the straight line $y' = a'x' + b$; when Δx increases to $d_{\min}$, we can use sum and $interval$ two values to determine whether the straight line segment with the slope of a' and length of $d_{\min}$ at point (x', y') exist in the image, finally, when sum is more than a set threshold, the algorithm can continue to run, and vice versa algorithm stops and thinks it cannot constitute a straight line.

3.2. Circle of improved Hough transform

Suppose the image is I , the set of pixel points in the space is E ; randomly select three points from E to calculate the circle with radius of R and center of (x, y), which is referred to as p_c and $sum_{p_c} = 1$,put p_c into the linked list set P ; and then randomly select three points from E ; and if the center and the radius are equal to a certain node in the linked list set P , it is supposed p_c and $sum_{p_c} = sum_{p_c} + 1$, then determine whether sum_{p_c} is more than a threshold N_t ; if it is greater than N_t then the circle with radius of R and center of (x, y) is considered as a candidate circle; determine pixel points number M_{p_c} of E in the candidate circle, if M_{p_c} is greater than a threshold M , then the candidate circle is considered as formal circle, so it cycles like this and the cycle stops when the cycle time is equal to $K_{\max}$, at this time the lookup process of Hough circle ends. The above search process is the basic idea to find the Hough circle transform.

Three points may determine a circle, so for given three points v_1, v_2, v_3 we can calculate the coordinate of the center and radius, which is calculated by formula (9) below.

$$\begin{aligned} a_{123} &= \frac{\begin{vmatrix} x_2^2 + y_2^2 - (x_1^2 + y_1^2) & 2(y_2 - y_1) \\ x_3^2 + y_3^2 - (x_1^2 + y_1^2) & 2(y_3 - y_1) \end{vmatrix}}{4[(x_2 - x_1)(y_3 - y_1) - (x_3 - x_1)(y_2 - y_1)]} \\ b_{123} &= \frac{\begin{vmatrix} 2(x_2 - x_1) & x_2^2 + y_2^2 - (x_1^2 + y_1^2) \\ 2(x_3 - x_1) & x_3^2 + y_3^2 - (x_1^2 + y_1^2) \end{vmatrix}}{4[(x_2 - x_1)(y_3 - y_1) - (x_3 - x_1)(y_2 - y_1)]} \\ r_{123} &= \sqrt{(x_i - a_{123})^2 + (y_i - b_{123})^2}, i = 1,2,3 \end{aligned} \tag{9}$$

The mathematical expression of the circle in formula (9) is as in formula (11), (a, b) represents the center of a circle, r represents the radius, $v_i = (x_i, y_i), i = 1,2,3$; to judge whether the points around are on the circle determined by the selected three points, then we take $v_4 = (x_4, y_4)$; when d_4 satisfies the formula (11), it means v_4 is on the circle, the δ in the formula (10) represents a threshold value.

$$\begin{cases} d = r^2 - a^2 - b^2 \\ d_4 = \left| \sqrt{(x_4 - a_{123})^2 + (y_4 - b_{123})^2} - r_{123} \right| < \delta \end{cases} \tag{10}$$

$$2 \cdot x \cdot a + 2 \cdot y \cdot b + d = x^2 + y^2 \tag{11}$$

To realize random Hough circle transform algorithm requires randomly finding three points on the image, and then determine the center and radius by three points, but the three obtained points may have no association in the original image, while the probability of three points in the actual circle of the original image is very small; so for the way of selecting sample points of the random Hough transform we put forward corresponding improvements, the corresponding improvement idea is to first identify a point on the image; when this point is not an isolated point, continue the adaptive search along this point and we will get a line segment, this line segment is likely part of a circle; randomly select three points on this line segment, calculate the center and radius through these three points, thus greatly improving the algorithm efficiency of the random Hough circle transform.

Self-adaptive search algorithm includes the following three aspects:

1) When the starting point has multiple directions to choose from, you can randomly choose the route;

2) When it is not the starting point and there are multiple directions to choose from, if the other direction is similar to the main direction then the search is stopped; when there is no direction to search, then the endpoint also needs to stop the search;
3) The search for the next node is primarily based on the direction of last node.

CONCLUSION

This paper first introduces the application theory of linear transform and circle transform in traditional Hough transform in the volleyball scene detection, discusses the algorithm defects of the traditional Hough transform, and proposes an improved direction for the algorithm; it detail studies the improved algorithm of Hough linear transform, and analyzes the advantages of improved Hough linear transform and its effect in mesh belt detection; based on the study of improved algorithm of Hough circle transform - random Hough circle transform, analyzes the defects of random Hough circle transform algorithm, puts forward an self-adaptive search algorithm, if the self-adaptive search algorithm can be combined with random Hough circular transform algorithm then we can receive better volleyball detection effect.

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