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A CROP ROWS RECOGNITION BASED ON HOUGH TRANSFORM USING TEMPLATE MATCHING

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ABSTRACT

An improved crop rows detection presented based-Hough transform. In the paper, the two argument r、q of peaks in Hough space were mapped into the Cartesian coordinate system to extract straight line segments fitting the crop rows, in which the template matching was firstly designed to filter the noises from isolated, or scattering points, then the weighted averaging were employed to eliminate line segments family due to the peaks and pseudo-peaks in Hough space. Experiment results showed that the novel crop rows recognition method could extract perfect crop row line segments from real image with strong noises or disturbance, and it was real-time, robust against great area grass, loss of crop row, or lack of crop row information in real image, with high accuracy and availability.

Keywords: *Field Image, Hough Transform, Crop Row Lines Detection, Visual Navigation*

1. INTRODUCTION

Point-line duality was introduced by Hough in 1962 to detect straight lines in an image [1]. It was extended by Rosenfeld in 1969[2] and by Duda and Hart in 1972[3]. They developed the standard Hough transform, which has been a traditional method for straight-line detection in images [4]. Hough transform (HT) was used to detect the parameterized shapes by mapping original data in the image space into the parameter space [5]. The purpose of HT was to find the peak value (maximum) in the parameter space. The coordinates of a peak value in parameter space were corresponding to a shape in the image space [6]. Its major advantages include dealing with noise, degradation and partial disconnection and ease of realization. Many improved HT methods have been proposed to extract straight lines [7]. The experimental result indicated that the algorithm could overcome the impact of shadows and was efficient for the shadows and irregular noises, but the Hough transform seldom has been applied in a real-time system [8]. Hough transform to detect straight line segments used in farmland robot visual navigation system under natural light conditions is

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also achieved some success [9-11]. However, the inadequacy of the single crop row detection using HT can't ensure access to visual navigation system, but for the multi-rows structure identification, there still have many difficulties to deal with in the existing algorithms [12-14]. In this paper, a crop rows recognition based on Hough transform using template matching was proposed, in which the peak and pseudo-peak in HT space were integrated to overcome the difficulties of multi-rows lines extraction, and its real-timeliness, accuracy and adaptability was good.

2. DEFECTS OF HOUGH TRANSFORM FOR DETECTION STRAIGHT LINES

HT is used to detect straight lines in an image, in which the computation of the HT, accumulating votes in an array and searching the accumulator array for peaks are implemented to find the potential lines present in the input image [15], and its computation burden is huge for an entire image. For solving the problem, some researchers have proposed many improvements, such as the probabilistic Hough transform [16], randomized Hough transform [17] and hierarchical Hough transform [18]. Among the improved Hough transform algorithms, an important direction is to study the distribution of the peak in the parameter space by using least error squares [19] to obtain a more accurate line features. These methods are mostly based on complete line extraction, and its time and space consumptions are huge, especially, not to meet the real-time requirements for the farming field visual navigation system. HT is used to extract crop rows lines in vision navigation system in natural lighting, the main problems including the following three aspects:

1) The accuracy of the crop rows lines is not easy to control when the fitting crop rows lines need high accuracy, and the HT can not be used [20].

2) Due to the broken crop row, loss of the crop row, or the large area weeds, the features of the crop rows lines extracted in the Hough transform space are replaced with the local peak maxima, and the peak points caused by the small line segments or noises produce pseudo peaks [17].

3) The target points are not continuous, and it is not easy to quantitate them due to the unbalance of light in field image. And the points belonging to a certain crop row line mostly not hold of strict distribution, and cumulative errors can gradually increase because of the small deviation in deciding the voting peaks.

Based on the existing problems in extracting multi-rows lines in the fields image using HT, the structural characteristics of the multi-rows lines is combined to recognize them by integrating the peak and pseudo-peak in HT space.

3. CROP ROW LINES DETECTION BASED ON HOUGH TRANSFORM

3.1 Image Pre-Processing Template For Crow Rows Structure

Template matching can determine the position parameters in the entire image for a specific pattern by calculating the similarity. This paper first designed an n × 1 template to abstract the characteristics of crop rows structure (Fig.1). And then the matching process counted the number of pixels entering each grid. If the number of pixels in the n grids was less than n (n is a constant), removed the pixel scanned, and otherwise, kept the pixel. Thus some interrupters such as isolated points in the image could be removed in order to obtain the points which formed to be a similar crop row

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line. And those lining points could contribute the identification of the structure of crop row (n is concerned with the width of crop row and posing parameters of camera).

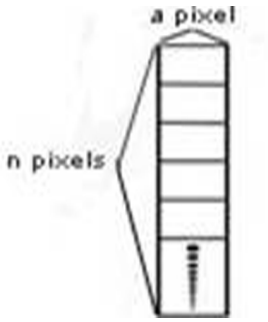


Fig.1 n×1 Grid for matching template

3.2 Weighted Average Of Peak And Pseudo-Peak To Remove Line Segments Clusters

Integrating the maximum of accumulator and surrounding pseudo-peaks to determine the final q and r corresponding to the line segment recognized. Judgment is as follows:

1) In the HT space, find the peak $value_{\max}$ in the accumulator, the peak corresponds to the parameter $M_{\max}(r_{\max}, q_{\max})$.

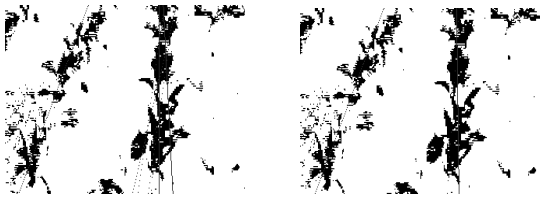
2) Looking for pseudo-peak point $M_i(\rho_i, \theta_i)$ around $M_{\max}(\rho_{\max}, \theta_{\max})$. These pseudo-peaks are close and easy to form some straight line segment clusters.

3) Integrating the peak parameter $M_{\max}(\rho_{\max}, \theta_{\max})$ and pseudo-peak parameters $M_i(\rho_i, \theta_i)$ using Eq.(1) in order to determine the final q and r of the line segment recognized,

$$p = \frac{\sum_{i=1} (p_i \times value_i) + p_{\max} \times value_{\max}}{\sum_{i=1} value_i + value_{\max}} \quad (1)$$

$$q = \frac{\sum_{i=1} (q_i \times value_i) + q_{\max} \times value_{\max}}{\sum_{i=1} value_i + value_{\max}}$$

Not only does this eliminate the interference of pseudo-peak or straight line segments clusters, but also can determine the location of the straight line segment.



(A) Result Of Performing HT (B) Result Of Integrating The Peak And Pseudo-Peak

Fig.2 Comparison Of The Crop Row Lines Extraction

Fig2. (a)was the result using Hough transform, there were several distinct straight line segment clusters along the crop rows. And these straight line clusters were caused by the peak and the pseudo-peaks. The weighted average processing about the peak and the pseudo-peak using Eq. (2) were implemented, shown as Fig2. (b).Obviously, the clustering straight line segments are eliminated, and the accurate crop row line segment is retained.

3.3 Solution Of The Parallel Lines

In standard HT equation, the r in HT space is positive, or perhaps negative, so that the line detected in the image space and the points in the HT space is not one-to-one, shown as in Fig.3, and its equation can be depicted as Eq.(2), where the parallel lines pair depend on the parameter y, and

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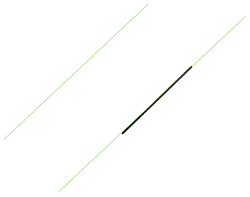
(A) Before Hough Transform



(B) After Hough Transform

Fig.3 Parallel Lines Produced By Using Normal Hough Transform

$$\left|x\cos(180-\theta)\right| + y\sin(180-\theta) = \left|x\cos\theta\right| + y\sin\theta \quad (2)$$

$$y = kx \pm b \quad (3)$$

the angles of two lines with the positive x direction are complementary. The parameters need to be treated in image space shown as in Eq. (3), along the crop rows, $q < p/4$, $p/4 < q < 3p/4$, respectively for the two parallel lines which hold of the information of the peak. Therefore, for the final goal of the crop rows lines identification, the steps as follows:

1) GVFE [21] is used to get the binary image of crop rows image.

2) The template matching process is performed to delete some obvious impossible points and lines segments across crop rows.

3) Voting on the arrays on the polar coordinates using traditional Hough transform.

4) Scanning all points in the polar coordinates, and find out the peaks and pseudo peaks ,then performing the weighted average process, recording the r、q.

5) Set dual-threshold $q_{\min}, q_{\max}$, and the q value defines which crop row line is right one. If $q_{\min} \le q < 90$, the crop row line is only; if $90 \le q \le q_{\max}$, then performing the process of the parallel crop row lines (in this paper, $\theta_{\min}$ determined by the prior knowledge, depending on the relations between the vision system and crop rows structure; $\theta_{\max}$ corresponding to the accumulator peak value $value_{\max}$).

6) Remove the peaks and pseudo peaks.

4. ANALYSIS OF DATA AND DISCUSSION

Fig.4. (a) is a typical image of crop rows of cole and sugar cane acquired after germination during the first fourth weeks of growth in a campus experimental field in South China Agricultural University, using a Germany Balser A301fc camera, and its soil backgrounds were very complex. The crop rows were segmented through the GFVE [21], and then processed to the binary image, shown as in Fig.4. (b)

(a) The original image

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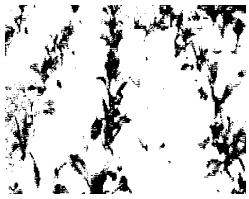


(b) The binary image

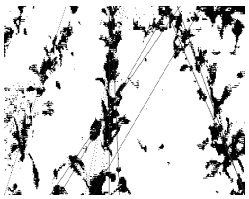
Fig.4 The Original Image With Its Binary Image

Fig.5. (a) showed the results obtained through using the traditional Hough transform. Obviously, there had been some straight line segment clusters, cross-rows line segments and parallel line segments. Fig.5. (b) showed the results obtained through using the algorithm in this paper, and obviously, those straight line segment clusters were substituted for only one, and the cross-rows line segments and parallel line segments were removed. The reason is as follows:

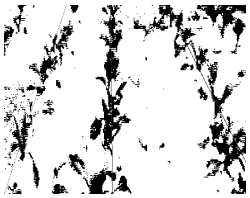
1) In this paper, the peak and the pseudo-peaks are integrated to eliminate the straight line segment clusters using the weighted average process, and the contribution of the peak along with the pseudo-peaks is provided to identify the crop row lines, which is available for most images of field crop rows and improved the adaptability of the traditional HT.

2) The detection of the cross-rows is mainly due to the width of the image processed greater than its height, so that the transverse voting accumulations are greater than that of the vertical voting accumulations, or caused by the great area of weeds. And the adoption of the dual-threshold is to ensure the crop rows lines detected in an appropriate range. In this study, two thresholds are $\pi / 4$, $3\pi / 4$, respectively, the angle of the line segment detected satisfying $\pi / 4 < a < 3\pi / 4$ ($\pi/4$ is an estimate depending on the posing parameters of the camera and the relative relationship between the camera and the crop rows lines, $3\pi / 4$ corresponding to the peak). In this experiment, the variable n is 5 in the image pre-processing template. For straight crop row lines, if n is too great, the running time may increase, and too small the accuracy of the peak in HT space is because the number of lines detected rises greatly.

3) For the parallel lines segments, shown as in Fig.5 (a), the number of votes is verified in Cartesian co-ordinates through transforming from the polar coordinates to retain the required line.



(a) Result of Traditional HT



(b) Result of the algorithm in this Paper

Fig.5 Comparison of crop row lines extraction

Generally, the field robot walking should be consistent with the crop rows structure, so the dual thresholds were to ensure that it could walk forwards along the crop rows. For curving crop rows, its curvature is often small, but it can be partitioned into some small crop row segments and then treated by using the algorithm presented in this paper. The template matching, weighted average and process of eliminating parallel line segments are not iterative calculations, therefore, the identification of the multi-rows has less time consumption. In this paper, all processes were in the

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VC++6.0 environment using the Dell Latitude E6400 notebook (dual core, each core is 2.4GHz), the time required only 0.7s, and met the requirements of the field robot at low speed.

5. CONCLUSION

In this paper, the dual-threshold and template matching were used to eliminate the cross-row line segments; and the accuracy of the crop row line extraction was improved through integrating the peak and the pseudo-peaks; the parallel line segments was treated through transforming polar co-ordinates to Cartesian co-ordinates in combination with C + + program design. The experimental results showed that the algorithm could extract multi-rows lines in the field image with good robustness and adaptability, and could deal with some situations such as incomplete crop rows, loss of structural information of the crop rows. And the proposed algorithm proved to be valuable for the field robot vision guidance system.

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