

## Wheat Rows Detection Based on Machine Vision

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### Abstract

*This study describes a new method for wheat rows detection at the middle growth stage based on Machine Vision. The algorithm includes three steps: (i) vegetation segmentation, (ii) centers points extraction and (iii) wheat rows detection. In the first step, color images were transformed into gray-level images and Otsu's method was used to implement binarization. Based on the fact that the corresponding center points on two adjacent horizontal scanning lines can't have a large deviation, in the second step, we firstly extracted the initial center points on the first scanning line based on a sliding window, and then gave a small shift based on positions of the initial center points which have been extracted on the previous scanning line to extract the center points for the next scanning line. Finally, the Randomized Hough transform (RHT) method was employed to locate the wheat rows. Test results indicate that the proposed method can effectively detect the wheat rows at the middle growth stage.*

**Keywords:** *Wheat rows detection; sliding window; center points; RHT*

### 1. Introduction

The agricultural production based on machine vision has become more and more popular in researched scientific field, which is widely used in fertilization, weeding and planting *etc.*, [1-2], for it reduces operator fatigue and improves vehicle positioning accuracy, improves efficiency, and enhances operation safety [3]. In literatures, numerous researchers and international experts studied in this area [4].

In order to achieve the goal of the automation work, it usually supplies accurate navigation information for the machine based on the center lines of the crop rows, for most crops are cultivated in parallel. Today, automation work based on computer vision is becoming the most studied approach. According to detecting the crop rows in images, the processes of vegetation protection and fertilization, *etc.*, can easily be performed automatically by guiding an autonomous machine. So, it is important to develop a reliable and accurate crop row detection method for the agricultural automation.

In the existing researches, many methods have been presented for detection of crop rows with image processing techniques. For the various detection methods, the methods based on linear regression and methods based on Hough transform (HT) are most commonly used. The first strategy "linear regression" based on the idea that the overall solution minimizes the sum of the squares of the deviation made in the results of each single equation. In [5], Billingsley and Schoenfisch applied linear regression using information based on three row segments to get guidance information of crop rows. And recently, Montalvo *et. al.*, proposed a crop row detection method in maize fields with high weeds pressure [6]. The algorithm includes three steps: image segmentation, double thresholding based on Otsu, and crop rows detection based on linear regression. Although their study was effectively in detecting crop rows in maize fields, some prior knowledge

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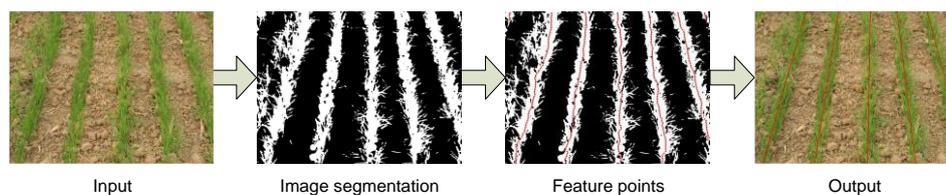
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limitations were still existed. Since their method was performed based on some special templates, the design of templates must be constructed under much previous knowledge like the location of each row in the maize image, the area to be detected in the image, which would bring some inconveniences and problems to application. In a word, linear regression is highly affected by image noise.

The method for crop rows detection based on HT is also one of the most commonly used methods in field of agricultural automation, especially for dealing with fields with weeds pressure or discontinuous rows due to its strong robustness and usefulness [7]. A lot of different applications of crop rows detection based on HT for real-time automatic navigation are known in the literatures [8-11]. The basic idea of the HT is to transform a difficult problem of line detection in image space into a relatively easy problem of point detection in parameter space based on the point-line duality. According to the coordinate transformation, the collinear points in image space correspond to concurrent lines in parameter space by voting. Despite its robust against noise, the computational burden associated to its voting scheme has prevented its agricultural applications to achieve real-time performances, except for very small images [12]. To avoid the large amount of calculation of HT, Xu, Oja, and Kultanen [13] proposed a RHT method. The core idea of the RHT is randomly select two edge pixels each time with equal probability in the image space and then their corresponding mapped point in the parameter space is accumulated by voting in an accumulator. The procedure is continued until some cells in the accumulator larger than a given threshold, at this moment, each of them represents a straight line. Similarly, in this paper, we also applied the RHT to our detection method.

The aim of our research is to develop a new method for accurate wheat rows detection at the middle growth stage. The specific goals are: (i) to develop a novel extraction method for estimating the center points indicating of wheat rows. (ii) To develop a real-time detection algorithm for wheat rows.

The flow diagram of the proposed approach is schematically displayed in Figure 1, which includes three steps. In the step of vegetation segmentation, *i.e.*, the gray-level transformation and binarization, the color indices  $2G-R-B$  and Otsu's method were applied to get the segmentation result. Then, in order to extract some center points indicating the wheat row centers, a novel extraction approach based on a sliding window on account of the fact that the corresponding center points on two adjacent horizontal scanning lines can't have a large deviation was proposed. Lastly, wheat rows were detected according to the RHT



**Figure 1. Flow Diagram of the Wheat Rows Detection Method, Which Contains Three Steps: (i) Vegetation Segmentation, (ii) Center Points Extraction, (iii) Wheat Rows Detection**

## 2. Material and Methods

### 2.1. Image Source and Experimental Equipment

The images in this study were obtained from the National Agricultural Research and the Chinese Academy of Agricultural plots demonstration bases in Beijing. The digital images were saved in RGB color space with the jpg format and with a resolution of

640×480 pixels. They were got under natural lighting in different seasons and years. Figure 2 displays a sample of the wheat images.

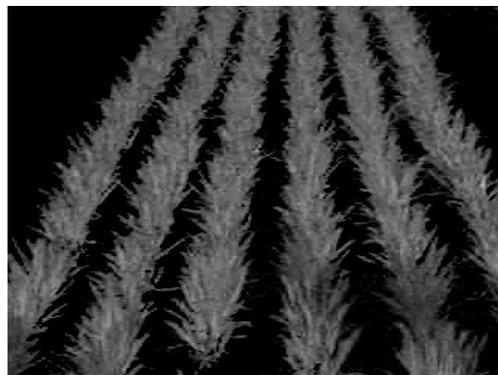
Image processing was performed using a personal computer with an Intel Core 2 Duo CPU, 2.60 GHz, 1.88GB RAM, and the algorithm was performed using MATLAB R2009a (Math Works) under a Windows 7 operating system.



**Figure 2. Original Image of Wheat Sample**

## 2.2. Vegetation Segmentation

**2.2.1. Gray-Level Transformation:** This step, aims to strengthen the contrast of backgrounds and living vegetations according to transforming a color image to a gray-level image with enhancing the green component and bating the blue and red elements. Here, a color index  $2G - R - B$  [14] was employed. Figure 3, shows the gray-level image obtained from the original image illustrated in Figure 2.



**Figure 3. Gray-Level Image Obtained with  $2G - R - B$  from the Original Image in Figure 2**

**2.2.2. Binarization:** Otsu's method [15], as one of the best global thresholding techniques which was used in many studies was applied to achieve the binarization in our study. Figure 4 shows the binarization image with the Otsu's method from the gray-level image illustrated in Figure 3. As expected, the living vegetations are separated from the rest and marked with white pixels while the rest are black.



**Figure 4. Binary Image Obtained with Otsu's Method for Image in Figure 3**

### 2.3. Center Points Extraction

Before detecting the positions of wheat rows, a number of center points indicating the centers of the wheat rows were extracted from a binary image. To get such center points, a sliding window, *i.e.*, a rectangle region  $W \times H$  ( $W$  is width of the window,  $H$  is height of the window) was constructed to scan a binary image from left to right, and top to bottom.

Based on the fact that wheat is growth in rows, it is not difficult to conclude that the corresponding center points on two adjacent horizontal scanning lines cannot have a large deviation. In view of this, we adopt two steps to extract the center points. Firstly, the initial center points were extracted based on a sliding window on the first horizontal scanning line. Then a small shift was given based on the positions of initial center points and the remaining center points were detected by a similar way.

**2.3.1. Initial Center Points Extraction:** In a binary image, the living vegetations are shown as white pixels while the backgrounds appear as black. Thus, when a window is sliding on a binary image, the number of white pixels in the window region is various. It is easy to get that the number of target pixels (white pixels) in the window will reach a maximum as long as the sliding window covers a wheat row region. The sum of target pixels (white pixels) in a sliding window region when centered at point  $(x, y)$  was defined as  $S_{(x,y)}$  and was calculated by Equation (1).

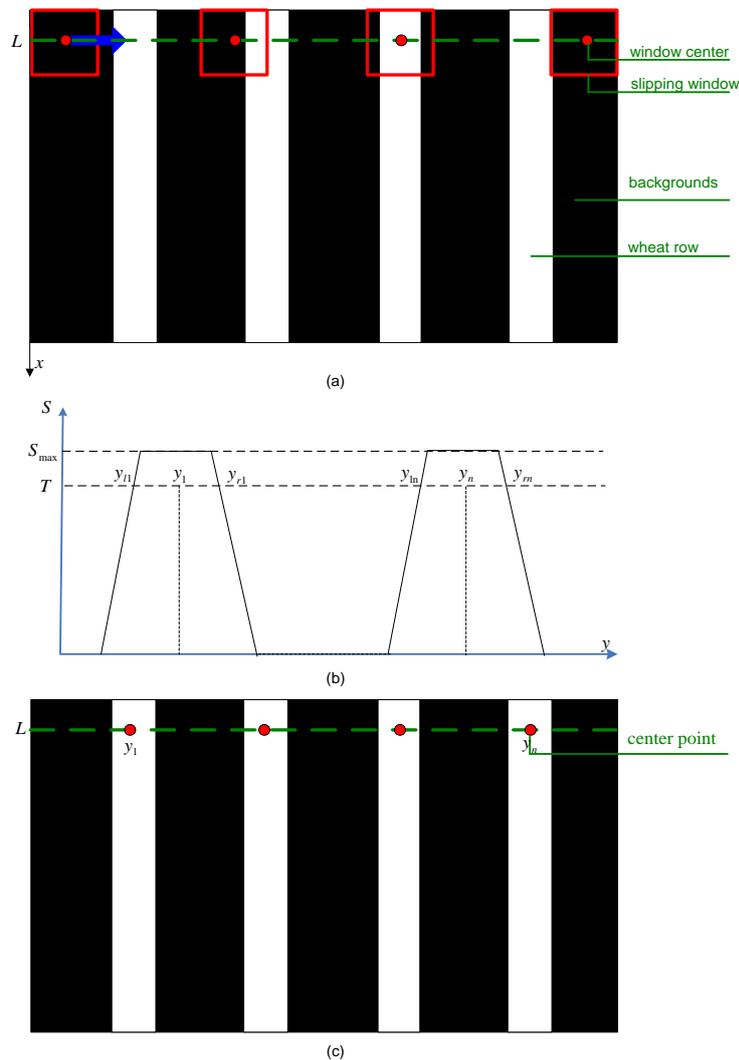
$$S_{(x,y)} = \sum_{i=x-H/2}^{x+H/2} \sum_{j=y-W/2}^{y+W/2} f(i, j) \quad (1)$$

Where  $f(i, j)$  represents the gray value of point  $(i, j)$ , the  $W$  and  $H$  are equal to 17, respectively.

The simulation process of initial center points extraction can be illustrated with a schematic drawing as Figure 5(a). Here, the four white strips symbolize wheat rows, respectively; the remainder black regions represent backgrounds; the red rectangle is a sliding window we constructed and the blue arrow refers to the window sliding strategy, *i.e.*, from left to right by column on the current scan line; line  $L$  is the horizontal scanning line which the initial center points were extracted from.

Figure 5(b), displays the corresponding changes of the sum of target pixels in the window for Figure 5(a), and how to get the initial center points on the first scanning line. In the figure,  $S$  represents the sum of target pixels in the window region.  $S_{\max}$  is the maximum value of  $S$ . However, in practice, the growth status of wheat can not be same absolutely, if regarding the maximum as a feature to obtain the wheat region is

inappropriately for it may lead to some wheat rows cannot be detected. We carried out a lot of experiments and obtained that when using a ratio value  $k$  ( $k=0.8$ ) to multiply by the  $S_{\max}$  and regarding the product as a threshold, the effect was best. That is, we firstly get the maximum value  $S_{\max}$  of  $S$ , then use a  $k$  to multiply by the  $S_{\max}$  and the product was regarded as a threshold and defined as  $T$ . The curve above the line  $T$  was regarded as a wheat region. The intersections of the  $T$  and line  $S$  are the edge points of the feature regions.  $y_{l1}$  and  $y_{r1}$  represent the start and end points of the first feature region. Similarly,  $x_{ln}$  and  $x_{rn}$  represent the start and end points of the  $n$ th feature region. Furthermore,  $y_1 = (y_{l1} + y_{r1}) / 2, \dots, y_n = (y_{ln} + y_{rn}) / 2$ .  $y_1, \dots, y_n$  not only are the midpoints of the start and end points of the first, ..., the  $n$ th feature regions, respectively, but also the center points of the wheat rows. The simulation result of the initial center points for the first horizontal scan line is illustrated in Figure 5(c),  $y_1, \dots, y_n$  are the center points.



**Figure 5. Schematic Drawing of Initial Center Points Extraction Process for Wheat Image on the First Horizontal Scan Line. (a) Sliding Process, i.e., from Left to Right by Column, (b) The Changes of Sum of Target Pixels in the Window, (c) Result of Initial Center Points**

The detailed process of the initial center points extraction are as follows:

*Step 1:* started from the origin point  $(x, y)$  of a binary image. The window center  $O$  (in Figure 5(a)) was defined as starting position. Scanned the image by column from left to right, and calculated each sum of target pixels in the window region according to Equation (1).

*Step 2:* Got the maximum value  $S_{\max}$  of  $S$ , and then used a ratio value  $k$  multiply by the  $S_{\max}$ , the product was recorded as:

$$T = k * S_{\max} \quad (2)$$

The region was regarded as a wheat region where the sum of the target pixels in the window was larger than  $T$ .

*Step 3:* Calculated the start and end points of the each wheat region, and then got the midpoints of the start points and end points. The midpoints were regarded as the center points of wheat rows. Figure 6 shows the result of the initial center points for Figure 4.



**Figure 6. The Result of the Initial Center Points for Figure 4**

**2.3.2. The Remaining Center Points Extraction:** After extracting the initial center points, it will consume much time for the extraction process on every scanning line if we adapt the above same strategy. In order to reduce the computing time, a novel approach which using a small shift based on the positions of the initial center points was designed to obtain the remaining center points taking into account of the fact that the corresponding center points on two adjacent horizontal scanning lines cannot have a large deviation.

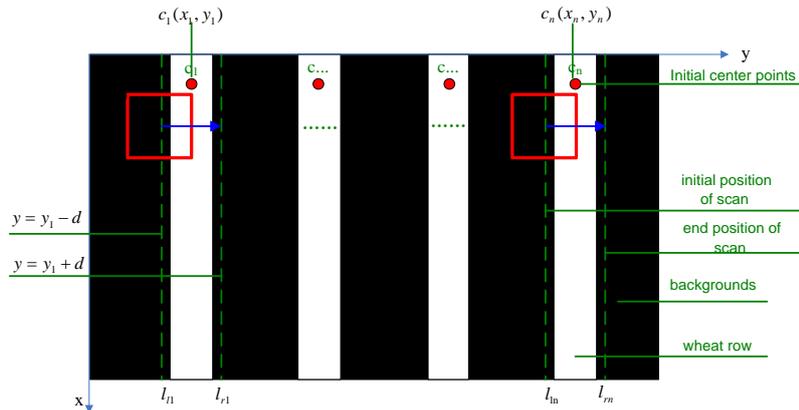
The core idea of our method is that, when we got the remaining center points on the next scan line after getting the initial center points of wheat rows, it is not to scan every column but give a small shift to left and right directions based on the positions of columns of each center point which have been extracted in previous scan line. Simultaneously, considering the fact that the wheat growth densely at the middle growth stage, it will be a much time-consuming process for the center points detection on every row, so we took a strategy which scanned every five lines for the following process.

The details were: (1) moved the window down five pixels, and then set a shift of 21 pixels based on the column of the previous center point to the left and right directions, respectively. (2) scanned the image by column with the new left and right borders as the starting and ending positions for each wheat row to obtain the center points of the current scanning. (3) Return to step (1) until the window reached the image bottom. The basic concept of the approach can be illustrated with a diagram as Figure 7.

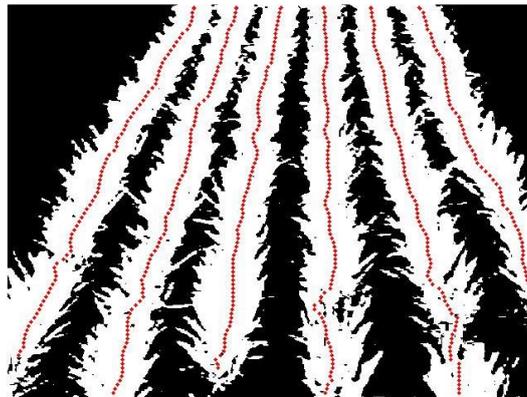
In Figure 7, set the center points  $c_1(x_1, y_1) \dots c_n(x_n, y_n)$  as the initial center points which have been detected in previous scanning line. The first wheat row, for

example, the starting scanning position and ending scanning position are  $(x_1 + 5, y_1 - d)$  and  $(x_1 + 5, y_1 + d)$ , respectively on the current scanning line. Similarly, for the  $n$ th wheat row, the starting scanning position and ending scanning position are  $(x_n + 5, y_n - d)$  and  $(x_n + 5, y_n + d)$ , respectively.

According to a lot of experiments we obtained that a shift of 21 pixels on the two directions (left and right) as the starting and ending positions is effectively. That is  $d = 21$ . As can be seen from Figure 8, all the center points of wheat image were extracted.



**Figure 7. The Schematic Drawing of the Remaining Center Points of Wheat Rows Based on Sliding Window**



**Figure 8. The Final Result of Center Points for Figure 4**

### 2.3. Wheat Rows Detection

After the center points are extracted, the next step is to give corresponding straight line equation to each wheat row.

The strong robustness and the small amount of calculation make RHT widely used in many researches. It is often to be used to find the best fitting straight line. According to randomly selecting two center points each time with equal probability in the image space and the corresponding mapped point in the parameter space is accumulated by voting in an accumulator to get a straight line. Here, we used the RHT method to get the wheat rows. As can be seen from Figure 9, all of the wheat rows were detected.



**Figure 9. The Final Result of Wheat Rows Detection**

### **3. Results and Discussions**

The proposed method was applied on more than 200 wheat images. The samples cover a wide range of situations, such as different illumination intensities, different backgrounds *etc.*

As Figure 2, displayed, the vegetations and the backgrounds have great difference in color, so color was regarded as the feature. So in the first step, the famous gray-level transformation method  $2G - R - B$  which enhances the green element inhibits the blue and red elements was used. From the image illustrated in Figure 3, it can be seen after emphasizing the green value, the living vegetations are identified from the original color image in Figure 2.

The gray-level image in Figure 3 was segmented with the automatic threshold method (Otsu), and a binary image (Figure 4) was obtained. After the thresholding, the living vegetations are white pixels and the rest appear as black. A lot of experiments on wheat images proved that the self-adaptation threshold algorithm was not affected by the light intensity and the soil background.

Figure 6 displays the initial center points obtained on the first scanning line from image in Figure 4. As can be seen from the figure, the center points can be extracted accurately based on the sliding window.

The result of all center points which got from Figure 6 is presented in Figure 8. Test results have shown that the scanning strategy which based on the previous scanning line each time is feasible; dimension of sliding window is  $17 \times 17$  is applicable; a shift of 21 pixels on left and right directions in the process of center points extraction is effectively. Thanks to the strong robustness, the method of center points extraction with less image noises.

Figure 9 shows the final result of wheat rows detection based on RHT. Experiments show that the method our proposed can not only saves computation time, and has a strong robustness.

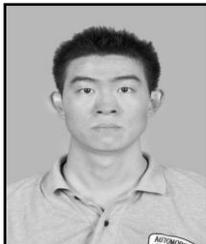
### **4. Conclusion**

In this paper, an approach of wheat rows detection at the middle growth stage is present. Considering the fact that the corresponding center points on two adjacent horizontal scanning lines can't have a large deviation, we proposed a novel extracting method to obtain the center points of wheat, which not only reduces the computation time but also enhance the robustness compared with existing methods. Simultaneously, the wheat rows were detected effectively by RHT which using the previous information of centers points.

## References

- [1] S. G. Mor and R. L. Clark, "DGPS-based automatic guidance-implementation and economical analysis", ASAE Paper, (2001), pp. 01-1192.
- [2] X. P. B. Artizzu, A. Ribeiro, M. Guijarro and G. Pajares, "Real-time image processing for crop/weed discrimination in maize fields", Computers and Electronics in Agriculture, vol. 75, no. 2, (2011), pp. 337-346.
- [3] S. Han, Q. Zhang, B. Ni and J. F. Reid, "A guidance directrix approach to vision based vehicle guidance systems", Computers and Electronics in Agriculture, vol. 43, no. 3, (2004), pp. 179-195.
- [4] J. Zhang, R. Wang, C. Xie and R. Li, "Crop Pests Image Recognition Based on Multi-features Fusion", Journal of Computational Information Systems, vol. 10, no. 12, (2014), pp. 5121-5129.
- [5] J. Billingsley and M. Schoenfish, "Vision-guidance of agricultural vehicles", Autonomous Robots, vol. 2, no. 1, (1995), pp. 65-76.
- [6] M. Montalvo, G. Pajares, J. M. Guerrero, J. Romeo, M. Guijarro, A. Ribeiro, J. J. Ruz and J. M. Cruz, "Automatic detection of crop rows in maize fields with high weeds pressure", Expert Systems with Applications, vol. 39, no. 15, (2012), pp. 11889-11897.
- [7] P. V. Hough, Washington, DC: U.S. Patent and Trademark Office, U.S. Patent No. 3,069,654, (1962).
- [8] S. Ericson and B. Åstrand, "A vision-guided mobile robot for precision agriculture", In Proceedings of 7th European conference on precision agriculture, Wageningen Academic Publishers, (2009).
- [9] C. Gée, J. Bossu, G. Jones and F. Truchetet, "Crop/weed discrimination in perspective agronomic images", Computers and Electronics in Agriculture, vol. 60, no. 1, (2008), pp. 49-59.
- [10] D. C. Slaughter, D. K. Giles and D. Downey, "Autonomous robotic weed control systems: A review", Computers and Electronics in Agriculture, vol. 61, (2008), pp. 63-78.
- [11] V. Leemans and M. F. Destain, "Application of the Hough transform for seed row location using machine vision", Biosystems Engineering, vol. 94, no. 3, (2006), pp. 325-336.
- [12] L. A. Fernandes and M. M. Oliveira, "Real-time line detection through an improved Hough transform voting scheme", Pattern Recognition, vol. 41, no. 1, (2008), pp. 299-314.
- [13] L. Xu, E. Oja and P. Kultanen, "A new curve detection method: Randomized Hough transform (RHT)", Pattern Recognition Letters, vol. 11, no. 5, (1990), pp. 331-338.
- [14] H. T. Sogaard and H. J. Olsen, "Determination of crop rows by image analysis without segmentation", Computers and Electronics in Agriculture, vol. 38, (2003), pp. 141-158.
- [15] N. Otsu, "A threshold selection method from gray-level histograms", IEEE Trans. Syst. Man Cybern. vol. 9, (1979), pp. 62-66.

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