A New Line Detection Algorithm - Automatic Measurement of Character Parameter of Rapeseed Plant by LSD

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***Abstract*—Molecular biology shows that phenotype of the crop is the ultimate concern in the research of crop yield, and to evaluate quality of results of the selective breeding, and it's also needed to acquire ideal plants by measuring each key parameter of phenotype of the crop, so as to popularize them. This article takes general rapeseed plant as researching example. Through adopting the new automatic measurement method-LSD (Line Segment Detector), it extracts line segments of image of the rapeseed plant rapidly; Then we joint and combine the extracted line segments that belong to the same stem, and adopt reasonable threshold value restriction respectively at different stages to remove the line segments having few contributions; finally, on the basis of the endpoint information of the whole jointed line segment and proportional scale relationship of the reference substance, we calculate the overall plant height, height of the first effective branch and length of the branch. At the end of the experiment, the measuring result of this article is compared with the parameter value acquired by measurement of high precision laser scanner. The result shows that: measuring error of plant height is within 3.9% and that of other parameters is less than 1.3%.Thus it proves that the method proposed in this article is effective, it can automatically extract and measure parameters of rapeseed plant phenotype and lay the foundation of researching relationship between phenotype parameters and yield and mechanized production, so as to better guide field work; Moreover, due to the high speed, low price and large quantity of memory space of measurement based on two-dimensional space, it has more benefits in the practical application.**

Keywords—LSD; Character Parameter; Rapeseed Plant; Automatic Measurement

I. INTRODUCTION

Rapeseed plant is one of the important oil crops of our country and has great strategic and economic significance. The research on correlated character parameters of rapeseed plant plant types not only can provide data basis to the selection and authentication of ideal plant type of rapeseed plant[1], but also can promote the mechanized production of rapeseed plant, and it especially has vital significance on the automatic measurement of the character parameters closely related to production and mechanized harvest, such as plant height, branch height (the first effective branch), length of branch, length of silique etc.

With the continuous development and integration of computer vision, digital picture processing technology and information technology, the domestic and foreign researchers have conducted researches on the automatic measurement of parameters of crop characters[2,3]: Ma extracted volume of corn ear by means of the picture processing method of HSV colorful space and the measurement accuracy rate is 94%[4];Shimizu designed a computer visual system consist of CCD camera and infrared lighting equipment[5]. It can calculate the length of its stem in three-dimension space according to the front and side pictures of verbena bonariensis shot simultaneously by placing a plane mirror that forms a 45 degree angle with the mirror surface of the camera behind the crop being measured to reflect, but the lengths of stem measured in this way under illumination and darkness will be widely different[6]. Ikeda developed a set of software used for analysis of characters of ear of rice, which is used for extracting characters of ear of rice, including each level branch of ear of rice, such as the quantity, length and quantity of insertion grain of the first branch, the second branch etc.[7]; By virtue of the designed CPRS(crop phenology recording system), Sakamoto figured out the agronomic parameters, such as leaf area index, biomass of the crop through the acquired visible light and near-infrared(NIR) pictures of corn and soybean during a continuous time series of day and night

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in developmental stage[8]. In general, in comparison with measurement of the related character parameters in three-dimension space, measurement on the basis of two-dimension space has the advantages of high speed, low price, great deal of data memory space and reasonable error precision. This experiment adopts the measurement based on two-dimension space.

The plant type selected in this research is general variety , but in view of the character that main stem and branches in the picture are chiefly formed by line segments, this article adopts a new automatic measurement method: LSD(Line Segment Detector)[9,10]. Compared with other line segment detection methods[11,12,13], the specialness of this method is the ability to detect the line segments in the picture rapidly, and it uses errors control method to make the detection result more precise[14,15]. It's a line segment detecting algorithm that can acquire accuracy at subpixel level within linear-time.First, acquire overall rapeseed plant plant that is detached from the background, and use this method to detect line segments in this picture rapidly; Then, joint the extracted line segments that belong to the same stem, and adopt reasonable threshold value restrictions to remove the improper line segments; Finally, figure out the overall plant height, height of the first effective branch and length of the branch according to the endpoint information of the jointed line segment and proportional scale relationship of reference substance. At the end of the experiment, compare the measuring results in this article with the parameter values acquired by measurement of high precision laser scanner. The result shows that: measuring error of plant height is within 3.9% and that of other several parameters is less than 1.3%, which proves the method proposed in this article is effective, and it can automatically extract and measure parameters of rapeseed plant phenotype and lay the foundation of researching relationship between phenotype parameters and yield and mechanized production, so as to better guide field work. Figure 1 is the flow diagram of this experiment.

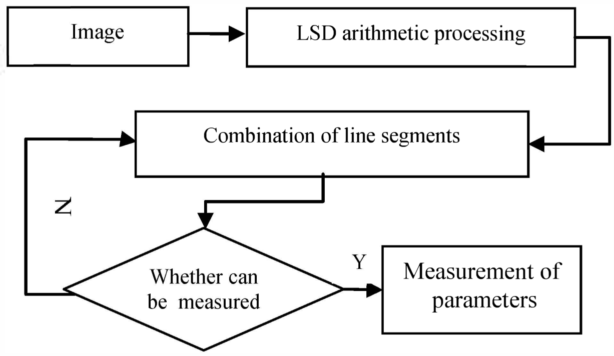


Fig. 1. Flow diagram of the experiment

Material and method

A. *Experimental field and crop*

Rapeseed plant variety selected in this article is the general variety and planting method of rapeseed plant is single plant pot culture.

B. *Image acquisition*

The images of rapeseed plant are taken by Canon digital single-lens reflex camera, with model number of Canon EOS DIGITAL REBEL XS.

C. *Line segment detection method-LSD*

LSD is a new image line segment detection method proposed by Rafael et al in 2010, based on the arithmetic of Burns, Hanson and Riseman. In comparison with other line segment detection methods, the specialness of this method is the ability to detect line segments in the picture rapidly, without the need of adjustment of the parameters; Simultaneously, it uses errors control method to make the detection result more precise and it's a line segment detecting algorithm that can acquire accuracy at subpixel level within linear-time.

The goal of LSD arithmetic is to detect partial straight outline in the picture and gray picture will be actually input, so it's needed to convert the acquired color images into gray images before the input. It will output a series of detected line segments, mainly including the following six processes:

1.Zoom the input gray images into 80% of its original size to eliminate the sawtooth effect in the images;

2.In order to reduce the mutual dependency between pixel points in the process of gradient computation, the template of 2x2 is used to do gradient computation;

3.To pseudo sort the gradient amplitude;

4.Confirm appropriate graded threshold value to delete the pixel points in the flat region or slowly changing region;

5.Iterate over all pixels and get a series of region with lines supported;

6.Model the edge of straight line according to the estimation of rectangle.

D. *Growth of Connected Line Segment*

Line segments detected directly by LSD arithmetic are short in a large quantity, so it's needed to adopt technical means to joint and combine the line segments that belong to the same stem. And it's also necessary to set reasonable threshold value in each stage to delete part of the shorter line segments and thus make the experiment better.

Thereinto, it's a relative concept to set reasonable threshold value to delete the shorter line segments, that is to delete the line segments that have little function to the next process. And the line segments with different lengths have different function in different stages. So, we need to set different threshold values to delete line segments through a great deal of experiments depending on corresponding situation.

1) *Preprocessing*

Assuming that there are n line segments detected by LSD arithmetic, we need to figure out the slope value and length of each ling segment.

If the two endpoints of the line segment are respectively (x_1, y_1) and (x_2, y_2), its slope is k and length is d.

$$k = \frac{y_2 - y_1}{x_2 - x_1} \tag{1}$$

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{2}$$

Since the cosine value shall be solved by using slope value and line segments that are too short are meaningless for research, the line segment with meaningless slope value($x_1 = x_2$)or distance d less than the specified threshold value will be removed to simplify the arithmetic.

2) Jointing of Line Segments

Assuming that the two line segments are l_1 and l_2, these two shall be jointed together if they meet the following three conditions at the same time:

Condition 1: The angle they form θ is less than the threshold value of the angle. Figure out the angle formed by these two line segments, based on the formula (3), which is to solve cosine according to slope value.

$$\theta = \arccos\left(\frac{|k_1 k_2 + 1|}{\sqrt{k_1^2 + 1}\sqrt{k_2^2 + 1}}\right) \tag{3}$$

Condition 2: Each of l_1 and l_2 has two endpoints, and four line segments can be obtained by jointing the four endpoints, as shown in figure 2;

Length of the four line segments are respectively d_1, d_2, d_3, d_4. Figure out the shortest line segment $d = \min(d_1, d_2, d_3, d_4)$. Assume the threshold value of distance as η, and the conditions for jointing are met if $d < \eta$;

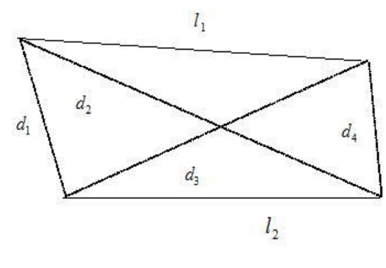


Fig. 2. Connection of line segments' endpoints

$$\begin{cases} d_1 = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \\ d_2 = \sqrt{(x_1 - x_2')^2 + (y_1 - y_2')^2} \\ d_3 = \sqrt{(x_1' - x_2)^2 + (y_1' - y_2)^2} \\ d_4 = \sqrt{(x_1' - x_2')^2 + (y_1' - y_2')^2} \end{cases} \tag{4}$$

Condition 3: Double of the shortest line segment is less than any other line segment;

Meanwhile, it's less significant to research the relatively short line segments. Delete all line segments that still are less than t after jointing by setting reasonable threshold value of length t again.

3) Combination of Line Segments

In order to make up the deficiency of the approximate parallel between two line segments, which haven't been considered in the first jointing, it's necessary to conduct combining work again, that is, it's mainly to combine the approximate parallel line segments in this stage. The combination should meet the following conditions:

Condition 1: Same as Condition 1 of the first jointing, it shall meet the condition that line segment angle θ is less than the fixed threshold value δ of angle;

Condition 2: Set a new threshold value of length k, and other conditions are the same as condition 2 of the first combination;

Condition 3: Figure out the normal distance h between the two line segments by building a triangle.

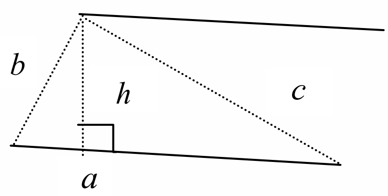


Fig. 3. Construction of Triangle

As is shown in Fig 3: convert the normal distance h into the height of the triangle and area of triangle can be figured out by Heron's formula ,as shown in equation (5), S is the area of triangle and a, b, c are respectively the length of sides of the triangle. The formula of triangle area is given in equation (7), in which a is the length of bottom edge, and h is the height correspond to the bottom length of side. We can get h and then set normal threshold of distance λ to make $h < \lambda$.

$$S = \sqrt{p(p-a)(p-b)(p-c)} \tag{5}$$

$$p = \frac{a+b+c}{2} \tag{6}$$

$$S = \frac{1}{2}ah \tag{7}$$

II. Result and discussion

In order to avoid the influence of the excessive and complicated background on the line segment detection results of crops, we should select, to the greatest extent, simplex filming background without other sundries when originally taking the rapeseed plant images. In this experiment, we select a white wall as the background to take rapeseed plant images. In view of the measurement of phenotype parameters of crops later, the reference substances should be placed as a mark during the shooting. In the experiment, a piece of memo paper with a length of 7.6cm and a width of 5cm is placed as reference substance.

A. LSD processing analysis

Figure 4(a) is the original image of rapeseed plant we collected, and we will process this picture with elementary LSD line segment detection. According to statistics, there are totally 2137 line segments that have been detected out, and the result is shown in Figure 4(b). We can find out based on the detection results: the line segments acquired through the processing of LSD arithmetic mainly can represent the overall outline of rapeseed plant, but the line segments acquired are massive and very short, and it's impossible to conduct following measurement of phenotype parameters.

(a) Original image (b) Result of LSD (c)Preprocessing Result

Fig. 4. Images of different stage

B. Follow-up processing and analysis

We will explain and analyze the experimental results of the three processing procedures respectively:

1) Preprocessing Result

Preprocessing procedure is to conduct the first setting of threshold value and delete line segments that will have little effect on the following connection and combination procedures as many as possible. Through a large number of experiments, this article finally confirms 15 as the threshold value, and then we process Figure 4(a), with results shown in Figure 4(c). There are totally 1761 line segments after the preprocessing. 18% of the useless line segments have been deleted.

2) Connection of Line Segments results

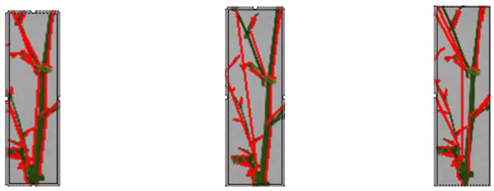
Some extracted line segments should have belonged to the same branch, but the they have showed a disconnect state because of shape peculiarity of plant etc. So we need to use maths method to connect them. Through plenty of experiments, this article confirms 20 as threshold value of distance and 15 degree as threshold value of angle.

Improper setting of threshold value of distance η and threshold value of angle δ will affect the connection effect. Figure 5 shows the connection results of three different threshold values of distance and threshold values of angle. In order to observe comparison result more clearly, we mark the same area of three images and then zoom in to observe. Figure 6 is the fractionated gain of rectangle block images of the three images, and it can be clearly seen: when δ =30, and η =20, line segment on the side of main stem connects with line segment of the third branch; when δ =15, and η =30, although the line segment of stem and lateral branch can be connected well, connection degree with the stem is not enough; when δ =15, and η =20, line segments of main stem and lateral branch not only can be connected ,but also can cling to the stem after connection.

It can be found form Figure 5(a) that the connected line segment can present characteristics of rapeseed plant better, but the number of line segments is still large, so it's unfit for measurement and need further processing. At this moment, we need to set threshold value for the second time. Through a great deal of experiments, we confirm 250 as the threshold value, then traverse the whole matrix and extract all the unmarked line segments with length longer than 250, that is to get the figure of results of line segments connection.

(a) δ =15, η =20; (b) δ =30, η =20; (c) δ =15, η =30;

Fig. 5. Effects of different threshold values of angle and distance



(a) (b) (c)

Fig. 6. Figure of fractionated gain

As shown in Figure 7, there are totally 28 line segments and it can be found that the acquired line segments can basically cover the main stems of the whole rapeseed plant plant.

Fig. 7. Result figure of connection

3) Combination of line segments

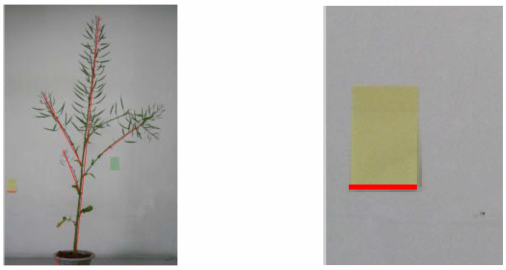
By looking into Figure 7, it can be found that, the main stems still can't be presented with one line segment, although the number of line segment reduce sharply, and sometimes, even two parallel line segments appear at the same time. The reason for this is that line segments have been detected on both sides of some stems when conducting line segment detection. So, we need to combine two approximate parallel line segments.

The threshold value of angle of line segments combination δ is still 15 degree, but setting of improper threshold value of distance κ and threshold value of normal distance λ will both significantly affect the combination result. Then we will demonstrate the processing result under the three different groups of threshold value of distance and threshold value of normal distance, as shown in Figure 8. It can be clearly found that the information of the stem of rapeseed plant stem can't be well described under Situation 8(b) and 8(c). Through plenty of experiments, the final threshold value of distance κ we confirm is 150 and threshold value of normal distance λ is 25, as shown in Figure 8(a).

(a) κ=150, λ=25; (b) κ=200, λ=150; (c) κ=25, λ=150;

Fig. 8. Combination results of different threshold values

Finally, by the third time setting of threshold value, we extract line segments that can describe stem of the crop directly. By a great number of experiments, the final threshold we select is 500, and we extract the line segments that is longer than 500 from the data set to get the final effect of processing, as shown in Figure 9(a). At this time, it can be visually seen that the stem of rapeseed plant can be absolutely described by 4 complete line segments, and thus it will become convenient to measure the relevant phenotype parameters of rapeseed plant.



(a) Final processing result (b)Reference substance

Fig. 9. Images of Final processing result and Reference substance

C. *Measurement and analysis of phenotype parameters*

According to figure of the final processing effect, we can visually find that every stem of the rapeseed plant plant can be replaced by a line segment. So, measurement of the length of branches of rapeseed plant can be converted into the measurement of length of the corresponding line segment. In accordance with coordinate positions of the two endpoints of each line segment, we can figure out length of stem in the picture by virtue of mathematical formula; Then according to the relationship between the length of reference substance in the picture and actual length,as shown in figure 9(b), we can figure out the actual length of each stem by proportional scale, so as to realize the measurement of related phenotype parameters of rapeseed plant.

In the end, we compare the parameter values acquired from experiments with the parameter values detected by the most precise portable 3D canner (HANDYSCAN 3D) in the market so far which is made by Creaform, and figure out the corresponding deviation on the basis of parameter value acquired by laser scanner. The result is shown in Table I.

TABLE I. COMPARISON OF PARAMETERS

Parameters name	Experimental value（cm）	Reference value（cm）	Relative deviation（%）
Height of plant	140.2157	138.4785	1.254
Height of branch	32.0063	30.8073	3.892
Length of the first branch	25.5938	25.7561	0.6301
Length of the third branch	47.2647	47.8847	1.295

It can be seen from Table 1 that: (1)The deviation of height of plant, height of the first branch and height of the third branch measured by this experimental method is within 1.3% in comparison with the value measured by high precise laser canner; (2) Compared with the value measured by high precise laser canner, deviation of height of the first branch measured by this experimental method is only 0.6301%, which can be ignored; (3) Compared with the value measured by high precise laser canner, the deviation of height value of branch of rapeseed plant(the first effective branch) is within 4%. So, the values acquired by this experimental method all can greatly demonstrate the phenotypic characteristics of rapeseed plant, such as height of plant, height of the first effective branch, height of the first branch and the third branch; besides, the measurement of parameters based on two-dimension space has the advantages of high speed, low price and large memory space and can better meet the actual demands of agriculture.

III. CONCLUSION

Line segment detecting method in this article is a line segment detecting algorithm that can acquire accuracy at subpixel level within linear-time. Compared with other traditional line segment detecting methods, it not only can detect line segments in the picture, and it can make detecting result more precise by using error control. Then, this study adopts appropriate technics to connect and combine the extracted line segments, and finally, the corresponding stem of rapeseed plant is replaced with a complete line segment successfully and thus it realizes the measurement of relative phenotypic parameters of rapeseed plant. The results show that the method proposed in this article is effective and feasible, and it can automatically extract and measure phenotypic parameters of rapeseed plant and lay the foundation of researching the relationship between phenotypic parameters and yield and mechanized production and thus better guide the field work; meanwhile, because of the high speed, low price and large quantity of memory space of measurement based on two-dimensional space, it can result in more benefits in the practical application.

In the experiment, the conversion of actual values of relative parameters of rapeseed plant is conducted based on the relationship of the proportional scale of reference substance. However, since the reference substance and rapeseed plant don't exist at the same level, the image formation of plant of rapeseed plant that is close to camera lens is a little bigger than the plant of rapeseed plant that is slightly farther from camera lens when film. But in the experiment, it didn't consider the deviation occurred in this situation in the deviation calculation. Hence, we will improve in future experiments. In the meantime, this article researched single plant rapeseed plant of pot culture, and next, we will adopt the same method to research rapeseed plant of collective field plantation and do statistical analysis on the results of the research.

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REFERENCES

[1] Pieruschka R, Poorter H. Phenotyping plants: genes, phenes and machines. Functional Plant Biology, 2012, 39(11): 813-820.

[2] Casady W W，Singh N，Costello T A. Machine Vision for Measurement of Rice Canopy Dimensions [J]. Transactions of the ASAE. 1996，39(5)：1891-1898.

[3] Ma Q, Jiang J T, Zhu D H, et al. Rapid measurement for 3D geometric features of maize ear based on image processing[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(supp.2): 208-212.

[4] Xiang H, Tian L. An automated stand-alone in-field remote sensing system (SIRSS) for in-season crop monitoring. Computers and Electronics in Agriculture, 2011, 78(1): 1-8

[5] Shimizu H，Heins R D. Computer vision based system for plant growth analysis[J]. Trans of the ASAE，1995，38(3)：958-964.

[6] Ikeda M, Hirose Y, Takashi T, et al. Analysis of rice panicle traits and detection ofQTLs using an image analyzing method. Breeding Science, 2010, 60(1): 55-64.

[7] Sakamoto T，Anatoly A，Anthony L，et a1. An alternative method using digital cameras for continuous monitoring of crop status[J]. Agricultural and Forest Meteorology，2012，154.

[8] Xiang H, Tian L. An automated stand-alone in-field remote sensing system (SIRSS) for in-season crop monitoring. Computers and Electronics in Agriculture, 2011, 78(1): 1-8

[9] Rafael Gromphone von Gioi et al. LSD: A Line Segment Detector. Image Processing On Line，2012.

[10] Rafael Cromphone von Gioi et al. On Straight Line Segment Detection，3(2008):313-347.

[11] D.S. Guru*，B.H.Shekar，P..Nagabhushan. A simple and robust line detection algorithm based on small eigenvalue analysis [J]. Pattern Recognition Letters 25(2004) 1-13.

[12] P. Meer，L. Moisan，J. M. ,Edge detection by Helmholtz principle，IEEE Trans. Pattern Anal. Machine Intelligence. 23(2001):1351-1365.

[13] Jang，J.H.，Hong，K.S.，Fast line segment grouping method finding globally more favorable line segments[J]. Pattern Recognition，35(2002),2235-2257.

[14] Rafael Gromphone von Gioi et al. LSD: A Fast Line Segment Detector with a False Detection Control. Pattern Analysis Intelligence，4(2010):722-732.

[15] Cuneyt Akinlar*，Cihan Topal. EDLines: A real-time segment detector with a false detection control.Pattern Recognition Letters32(2011):1633-1642.