Fruiting Mother-Shoot Counting System Based On Segmented Images

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***Abstract*—To grow sweet grapes, it is important to be able to count the number of fruiting mother shoots accurately. In a previous study, segmentation of aerial photographs containing fruiting mother shoots and branches was conducted to count the number of fruiting mother shoots. However, counts were inaccurate for areas where fruiting mother shoots were incorrectly segmented into branches. In this study, a fan-shaped search method was proposed to correctly count shoots that could not be properly counted in that previous study. Experiments confirmed the effectiveness of the newly proposed method.**

Keywords-Smart Agriculture; Artificial Intelligence; Image Processing.

I. INTRODUCTION

To grow sweet grapes, it is vital to be able to determine the number of fruiting mother shoots properly. Most vineyards in Japan have adopted shelf cultivation, and farmers can only see a small area when they are working in the vineyard. However, aerial photography has made it possible to check the branching over a wide area [1]. Figure 1 shows an example of such an aerial photograph. The red outlined areas in Figure 1 represent the fruiting mother shoots extending from the upper left branch, which is outlined in blue.

Ito et al. [2] marked branch in red, fruiting mother shoot in yellow, and the rest in gray to produce teacher data for training SegNet [3] network. Thus, a neural network system was developed to separate branches from fruiting mother shoots in aerial photographs. Finally, they try to determine the number of fruiting mother shoots by counting the yellow region in the image.

Figure 2 shows the analysis results from the same aerial photograph shown in Figure 1 using the method proposed by Ito et al. From Figure 2, we can instantly see that the upper left branch has seven fruiting mother shoots growing from it.

The branches and the fruiting mother shoots in the aerial images used for testing in the first study were in the best ideal condition, with the fruiting mother shoot not being obscured by the branch. As a result, the fruiting mother shoot in the aerial image is also depicted in the recognition image as a single fruiting mother shoot, without any division. Therefore, there is no error when counting the yellow areas in the recognition image to determine the number of fruiting mother shoots. However, not all of the branches in the aerial image are actually in the best possible condition with respect to the fruiting mother shoot. One fruiting mother shot is counted as more than one in the calculation of the number of fruiting mother shoots if the fruiting mother shoot breaks during the recognition process for a variety of reasons, which results in an error. Ito et al. and others have failed to offer a workable answer to this issue.

In order to lessen the inaccuracies that can occur while counting the number of fruiting mother shoots, the purpose of this research is to propose a method for correct the divided fruiting mother shoots. Specifically, the following methods are used. First, the system automatically selects the areas that need to be corrected and the areas that do not need to be corrected. Then, it considers only the areas that need to be corrected as one area. Finally, it counts the number of fruiting mother shoots.

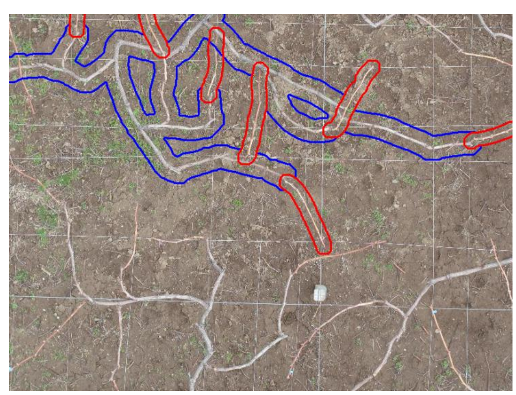

Figure 1. Aerial photograph with red outlined mother shoots

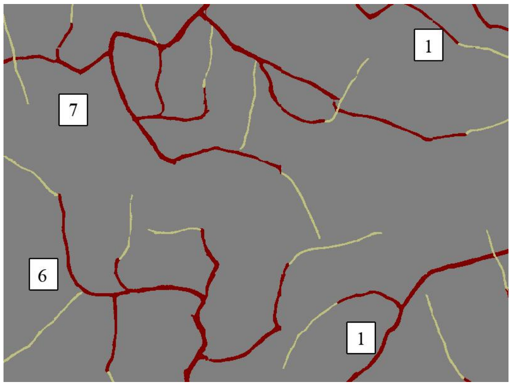

Figure 2. Segmentation analysis results

In Section 2, we will concentrate on the challenges in tackling this problem.

II. PROBLEM

In Section 1 we indicated that the output of SegNet occasionally contains incorrectly recognized areas. This error may cause the fruiting mother branch to divide, which could result in inaccurate count of its number.

Figure 3 shows another example of an aerial photograph, and Figure 4 shows a misidentification corresponding to the blue box in Figure 3. In the aerial photograph, there is only one fruiting mother shoot, but because it is partially misidentified as branch instead of a single fruiting mother shoot, there is a small division, and two fruiting mother shoots are counted. This problem, which was not addressed in the study by Ito et al., results in an incorrect final count when the number of fruiting mother shoots is aggregated.

The pixel range at the division in Figure 4 is 65px, and the area within this range is calculated to correct the figure. Figure 5 shows other errors generated when correcting Figure 4. The correction range can be adjusted, and the blue outline shown in the Figure 5 is the correction area formed when the correction range is 65px. If the area of the fruiting mother shoots in the correction area is corrected to one area, the number of fruiting mother shoots, which should be counted as two, will instead be counted as one. Therefore, the number of fruiting mother shoots cannot be calculated correctly only by adjusting this pixel range.

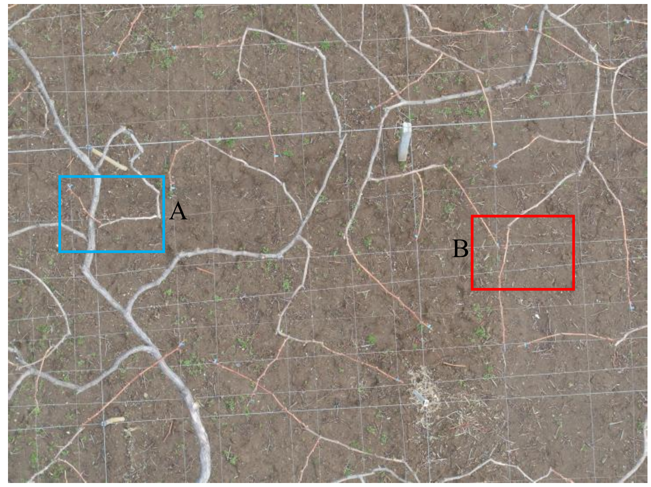

Figure 3. Aerial photography example

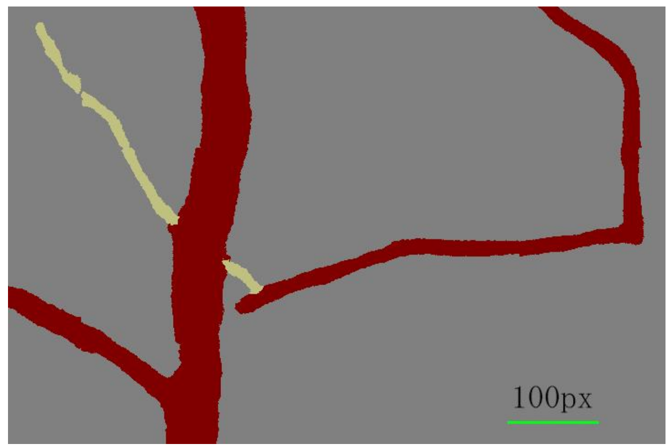

Figure 4. Divided single shoot counted as two

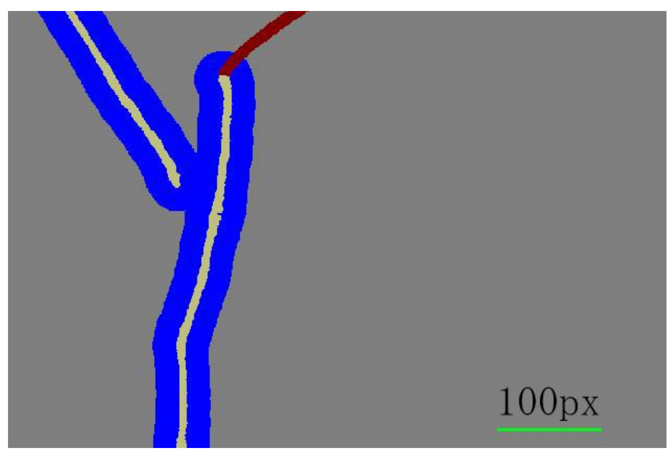

Figure 5. Falsely corrected shoot

In Section 3 we explain how we used a fan-shaped search to overcome this issue.

III. PROPOSED METHOD

The unique approach we have suggested for correcting a divided fruiting mother shoot in a recognition image will be the main topic of this section. We reviewed the data and found that there is no relevant correction method for the recognition images of branches. As a result, we had to change how we were thinking to address this brand-new subject.

The fruiting mother shoots has characteristics of grow as straight as possible [4]. Therefore, if there are two close fruiting mother shoots in the recognition image, when they are connected start for end, the whole fruiting mother shoot tend to be straight, or slightly curved to a certain extent. In that case, we can judge that these two fruiting mother shoots belong to the same divided single shoot.

If we ignore the width of fruiting mother shoot and take it as a line, then the problem can be reduced to the correct of straight line. Studies on line correct, such as fingerprint correct [5][6] and object contour correct [7], all have examples to analyze the vector and curvature at both ends of the broken part of line. Both vector and curvature are correlated to angles and directions. Therefore, for the correct in our study, we thought it would be a good idea to introduce angles and directions.

If we use the fan-shaped area to control the distance and angle of search, at the same time simulate the extension line at both ends of fruiting mother shoot along the extension direction to fix the direction of fan-shaped area. For example, as shown in Figure 6 and Figure 7, a fan-shaped search area is made at both ends of each fruiting mother shoot, through which the parts that need to be corrected can be found. The part that requires to be corrected in Figure 6 is between points B and C. We stipulate that if two endpoints appear in each other's fan-shaped area, the area between these two points shall be judged as the part that needs to be corrected.

Points C and D exist in the fan shape formed by point B in Figure 5. Point B exists in the fan shape formed by point C. Therefore, since points B and C are within each other's fan shape, the divided part will be corrected by connecting points B and C. Points A and D in Figure 5, points E and F in Figure 6 do not meet the judgment criteria, so these points will not be connected. Figure 8 and Figure 9 show the correct results after judging Figure 4 and Figure 5, respectively.

The process involved in the fan-shaped search method is described below.

(1) Find the two endpoints of a fruiting mother shoot.

(2) Make an extension line for each endpoint.

(3) Plot a fan-shaped area at the specified angle and radius using the extension line as the base.

(4) Search for other endpoints within each fan-shaped region.

(5) When the two endpoints are within each other's fan shape, connect only the single endpoint closest to the search target.

Through the fan-shaped search area, the divided fruiting mother shoots can be screened and corrected correctly.

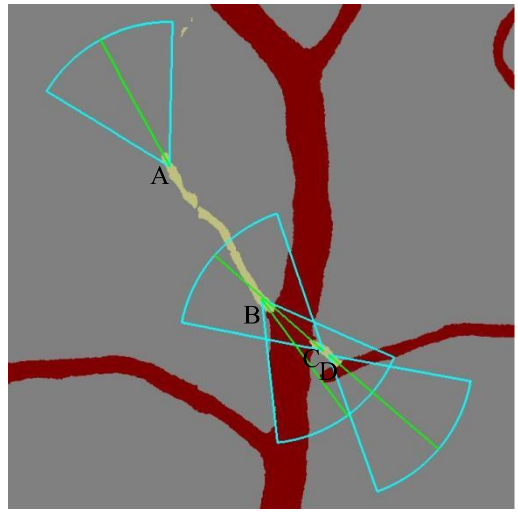

Figure 6. Fan-shaped area of A

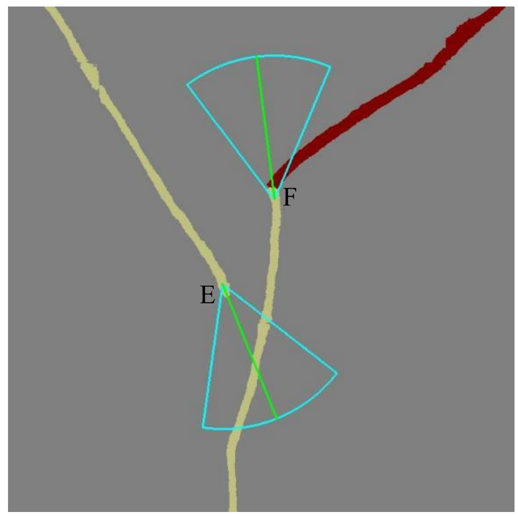

Figure 7. Fan-shaped area of B

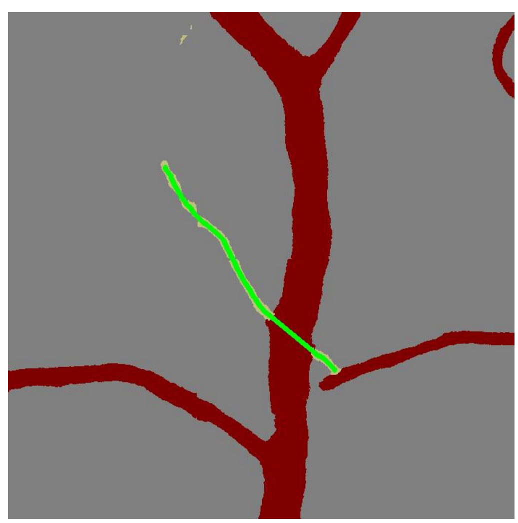

Figure 8. Correction result for A

 ISBN: 978-1-68558-057-5

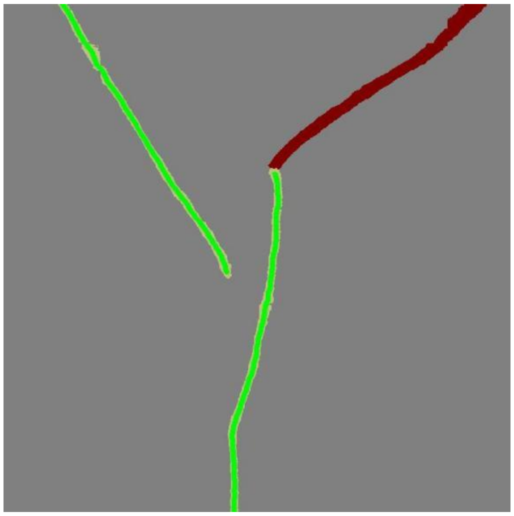

Figure 9. Correction result for B

We have created a comparative experiment for Section 4 to help further demonstrate the validity of the approach.

IV. EXPERIMENT

In this section, to verify the effectiveness of the proposed method, we compared the number of fruiting mother shoots counted by the method that corrects only by pixel range, and that by our method.

The images used for comparison were 12 vineyard aerial photographs in which there are fruiting mother shoots divided by branches. The correct number of fruiting mother shoots in the 12 images is 285. There are 57 fruiting mother shoots that need to be corrected.

Any of the fruiting mother shoots in aerial photograph can be counted correctly in recognition image within the following two conditions:

1. There is no single shoot being counted as two or more due to divided problem.
2. There are no multiple fruiting mother shoots being counted as one because of the error correct with other fruiting mother shoots.

The fruiting mother shoots that are counted correctly should contain those that can be counted correctly without correct and that can be counted correctly after correct. But the fruiting mother shoots with error correct should be excluded. Therefore, the accuracy of fruiting mother shoots that are counted correctly can be expressed by formula (1).

$$\text{Accuracy} = \frac{228 + \text{Number of Corrected} - \text{Number of False Corrected}}{285} \quad (1)$$

In the 12 images, the minimum range that needs to be corrected is 62px, and the maximum range is 173px. The minimum fan-shaped angle that needs to be corrected is 14°, and the maximum is 52°. For this reason, in this study, the radius threshold is set every 50px from 50px to 200px, and the angle is set every 20° from 20° to 60° for comparison.

Table 1 summarizes the results using the method of correcting only by pixel range, and Table 2 gives the results using the proposed method. The numbers in the upper line of each row are the numbers of fruiting mother shoots that were successfully corrected. The numbers in parentheses are shoots that were corrected erroneously. The lower line in each row shows the accuracy.

TABLE I. RESULTS CORRECTING ONLY BY PIXEL RANGE

200px	150px	100px	50px
57(53) 81.4%	55(18) 93.0%	52(14) 93.3%	0(0) 80.0%

TABLE II. RESULTS USING PROPOSED METHOD

	200px	150px	100px	50px
60°	57(2) 99.3%	55(2) 98.6%	52(0) 98.2%	0(0) 80.0%
40°	55(2) 98.6%	53(2) 97.9%	50(0) 97.5%	0(0) 80.0%
20°	49(2) 96.5%	47(2) 95.8%	44(0) 95.4%	0(0) 80.0%

For images in which the fruiting mother shoot is divided by branches, the method that corrects only by pixel range has a highest accuracy of 93.3% for a range of 100px. In the proposed method, when the radius is 200px and the angle is 60°, it a highest accuracy of 99.3% is achieved. This is a 6.0% improvement over the method using only the pixel range.

The experimental results demonstrate that, using the method that depends only on the pixel range, the accuracy decreases as the range increases because erroneous correction occurs. In the fan-shaped search method, the correction effect can be improved by extending the radius, and at the same time, erroneous corrections can be better avoided. Therefore, it is possible to improve the estimation accuracy of the number of fruiting mother shoots that are correctly counted.

V. CONCLUSION

In this study, we proposed a fan-shaped search method that is effective for aerial photographs where a fruiting mother shoot is divided by branches, resulting in a more accurate count of the number of fruiting mother shoots. Not only can the pruning efficiency of fruiting mother shoots be improved by quickly and accurately mastering the number of fruiting mother shoots, but also it is possible to accurately predict grape yield.

All images in the experiments used to investigate the effectiveness of the fan-shaped search method were taken for only one part of a single farm. In the future, we would like to make a panoramic image from the partial images of vineyards and correct the number of fruiting mother shoots in entire vineyards for accurate aggregation.

The research breakthrough takes the grape-growing process one step further towards full automation.

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