以機器視覺選別草莓苗

Strawberry Seedling Grading by Machine Vision

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摘　　要

本研究使用機器視覺系統選別草莓苗。擷取影像時，草莓苗係以一定之方位放置於背光枱上。影像擷取後，草莓苗影像先與背景分離，然後再收縮與擴張。選別係依據冠部直徑及根之數目與長度爲之。選別錯誤率爲百分之十六。

ABSTRACT

A machine vision algorithm for grading strawberry seedlings was developed. Seedlings were placed on a backlighting table in a fixed orientation. Grading was based on the diameter of the crown and the number and length of roots. The total grading error rate was 16 percent.

Introduction

Tens of millions of strawberry seedlings in the nursery have to be graded for sale each year. Grading is currently performed manually. It is not practical for the workers to measure the plants for grading, because in this way the grading work will be very slow. Instead, they grade the seedlings according to their experience. Hence, manual grading is subjective, unreliable, and slow. Moreover, good, experienced workers are difficult to find for this short, temporary job. These factors prompted this research.

The declining cost and increasing capabilities of microcomputers and digital image processing hardware have greatly increased the applications of machine vision techniques in industry and agriculture. In agriculture, machine vision was employed for plant identification (Guyer, et al., 1986), for fruit stem detection (Wolfe and Sandler, 1985), for apple sorting (Rehkugler and Throop, 1986), and for peach grading (Miller and Delwiche, 1988). Machine vision appears to be an ideal tool for addressing the seedling grading problem (Kranzler, 1985). Rigney and Kranzler (1986) applied machine vision to grade southern pine seedlings.

Materials and Equipment

Materials

Strawberry seedlings were obtained from Ahrens Nursery located at Huntingburg, Indiana. Seedlings were harvested in January 1988 and stored in a cooler in dormant state until tested in February. One hundred seedlings were used as samples.

Equipment

The hardware used for digital image processing was a DT-2851 Frame Grabber and a DT-2858 Auxiliary Frame Processor produced by Data Translation, Inc., Marlborough, MA. The two image processing boards were installed in an IBM-AT microcomputer which was networked to a Sun Microsystems Engineering Workstation (Sun 3/280) for images storage. The frame grabber digitizes an entire scene into a 480x512 array format with 8 bits resolution for each pixel. The digital image processing system includes a separate system monitor, SONY Trinitron Color TV Model KV-1311 CR, which is capable of analog and digital input, and a RCA Dimensia MVR975HF video cassette recorder.

Images were taken by a RCA Camcorder Model CMR 300 and stored on video tapes. The video camera has a zoom lens, auto-focus, auto-iris, auto-white-balance and macro functions. All the images were taken at modes of manual-focus, auto-iris and auto-white-balance. A backlighting table sized 66x52 cm with two 20-watt fluorescent light tubes was employed in image acquisition.

Image Acquisition and Processing

Image Acquisition

Leaves, if any, were removed and soil was shaken off from the seedling prior to placing the seedling on the backlighting table in an orientation such that its bottom of bud was approximately parallel to the vertical edges of the frame with the bud at top. The distance from Camcorder lens to the backlighting table was 106 cm. The fluorescent lights of the lab were on while videotaping. Each seedling was videotaped for about 15 seconds. The videotaped images were digitized and stored on computers and magnetic tapes by the use of DT-IRIS subroutines.

Image Processing

The videotaped image was digitized and thresholded at a gray level value of 115. This optimal threshold value was determined by using ImagePro to threshold several images at different gray levels. In an thresholded image, the seedling was black(0) and the background was white(255). Since the lighting condition and Camcorder settings were kept the same throughout the image acquisition process, the optimal threshold value was the same for all images. The thresholded image was then shrunk one time and expanded one time to smooth the edge for image analysis.

Algorithm

Algorithm was developed based on the facts that the crown was either located at the place where the curvature of the edge was minimum or where the thickness was minimum in the crown searching area defined later. The algorithm first located the position of the crown, measured crown diameter, then counted the number of roots which were 76 mm or longer from the crown. A seedling was graded as acceptable if it had a crown diameter larger than 8 mm and had at least ten roots equal to or longer than 76 mm. Sixty-six of the 100 samples were manually graded as acceptable, and

34 of them were cull.

A 50x50 mm square was used for calibration. The horizontal pixel resolution was found to be 0.65 mm/pixel and the vertical pixel resolution was 0.53 mm/pixel.

Crown Locating and Crown Diameter Measurement

The processed image was scanned horizontally from the top to the bottom. After a black pixel was found, the edge pixels of the image within 60 rows down from this black pixel were located by using the crack following method (Rosenfeld and Kak, 1982) as shown in Fig. 1. Fig. 2 is the original image of Fig. 1.

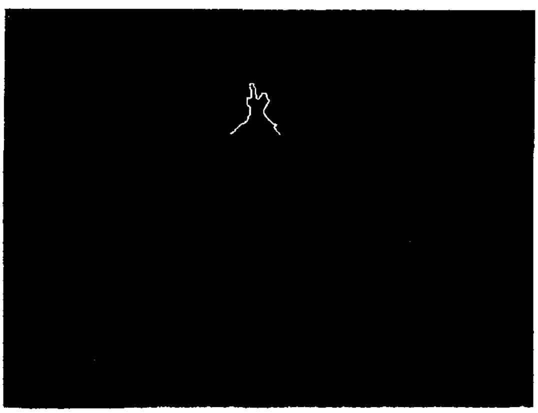

Figure 1. The edge of the top 60 rows of an image.

Figure 2. The original image of Fig. 1.

Each of the 60 rows was checked to see whether it contained white pixel(s) between the leftmost and the rightmost edge points. The portion which contained no white pixel was determined and was used to locate the crown. (Fig. 3). This portion was called the crown searching area.

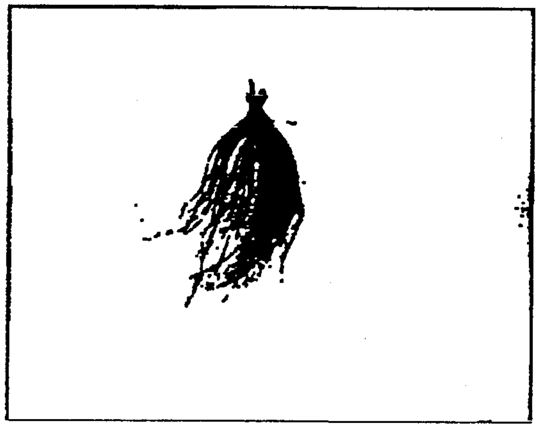

Figure 3. The crown searching area (between the two white horizontal lines).

The algorithm then found the point with minimum curvature for both the left-hand side and the right-hand side edges within the crown searching area. The curvature at a point P on the edge was the background side angle formed by the slopes of the two lines joining P to nine pixels along the edge on each direction. The slope of these two lines was the average of the slopes of each line joining P to each of the nine pixels. The number of pixels other than nine was tested and resulted in less accurate curvatures.

Next, the algorithm looked for the thinnest place of the crown searching area. The number of black pixels in a row was counted starting from the bottom row. If a row had more black pixels than its preceding row and if the number of black pixels was not greater than 34(22 mm), then the preceding row was a possible location of the crown. If the number of black pixels of this row was more than 34, it was not a crown location and this process continued.

Three possible locations of the crown had been found. The one which was lowest or had largest row number was considered as the crown location. Crown diameter was equal to the number of black pixels of the row where the crown located multiplied by the horizontal pixel resolution.

Root Counting

After the crown was located root counting could be conducted. The thresholded images were used for the root counting task. Because some roots were disappear after the shrinkage and expanding process, the processed images could not be used for root counting. The pixels on a semicircle which had a radius of 76 mm from the midpoint of the crown diameter were checked. In Fig. 4 all black pixels on this semi-circle were changed to white. Consecutive black pixels less than or equal to three were counted as. one root. All consecutive black pixels more than three were added together and divided by three to get the number of roots. The total number of roots which were 76 mm or longer was obtained by the addition of these two above numbers.

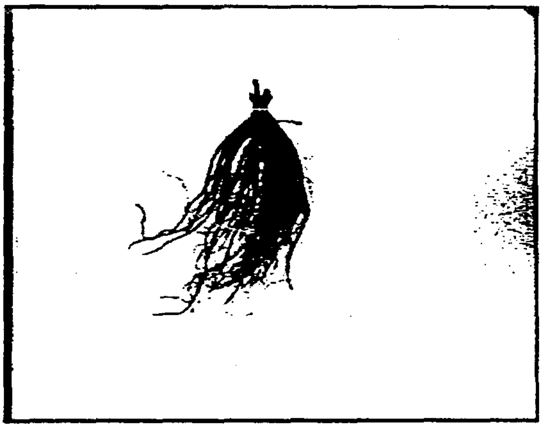

Figure 4. The crown diameter and part of the semicircle.

Results and Discussion

The grading results are shown in Table 1. Eleven of the 66 acceptable seedlings were graded as cull and five of the 34 cull seedlings were graded as acceptable. The total grading error rate was 16 percent. High grading error rate was due to the complication and variation of the shapes of strawberry seedlings, which made the crown locating task difficult. For some seedlings, the crown could not be located from their images even by the eyes. The overlap and unstraightness of roots decreased the accuracy of root counting. Roots were pulled straight when measured by hands.

Time required to grade a seedling was approximately 25 seconds, including restored the image from the image file to the frame buffer. In actual grading task image restoring time was not needed, because image was acquired from the camera and put in the frame buffer in real time.

Table 1. Grading Results

Acceptable Seedlings 66		Cull Seedlings 34	
Graded Acceptable	Graded Cull	Graded Acceptable	Graded Cull
55 83%	11 17%	5 15%	29 85%

Total grading error rate 16%

Conclusions

Due to the variation in shapes among strawberry seedlings, the total grading error rate, 16 percent, was high. Since the seedlings are tangled together, they need to be singulated by human before grading with machine vision. A more sophisticated algorithm is needed to grade the seedling placed in random orientation without removing the leaves if it has any.

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結　　論

㈠爲推行高粱移植栽培，選擇績優與熱心的專業化育苗中心來培育強壯箱苗，以供機械挿植，乃是成功之要訣。惟欲利用育苗中心之原有設備一貫作業播種機時，需加以更換輪種槽，才能控制每箱播種量在120～150公克。

㈡高粱移植試驗區共完成機挿面積爲8.60公頃，所採用挿秧機爲六行式，爲求使挿植行距保持各行平均爲60cm，需將挿秧機之指示桿加長爲30cm，否則於作業機調頭轉彎時需將秧苗搬動，至感不方便。

㈢以高粱移植區進行深層施肥試驗，初步結果對肥料用量之節省雖然數量不多，但對促進子實產量之提高有幫助，深施區較人工普肥區增產率約爲7.33%。

㈣引用稻作各項作業機來從事高粱移植區之栽培管理時，深受高粱與水稻之農藝性狀與栽培方式有很大差異，因此作業機也要略加改良，才能讓使用者感到滿意。

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