International Symposium “Root Research and Applications”
RootRAP, 2–4 September 2009, Boku – Vienna, Austria

Methods For Thresholding Minirhizotron Root Images

Teofilo Vamerali [1], *Andrea Ganis* [2] *and Giuliano Mosca* [2]

[1] Department of Environmental Sciences, University of Parma, Viale G.P. Usberti 11/A, 43100 Parma (Italy);
[2] Department of Environmental Agronomy and Crop Sciences, University of Padova, Viale dell’Università 16, 35020 Legnaro – Padova (Italy)
Contact: Teofilo Vamerali, Tel. +39.049.8272861, Fax +39.049.8272839, E-mail teofilo.vamerali@unipd.it

ABSTRACT

An approach to thresholding root images taken from minirhizotrons was tested on maize, based on the decomposition of an image into N sectors. A range of luminance thresholds was tested for binarizing each sector, and the most suitable depended on root age, whereas the best correlation between manual and automatic measurements of roots was obtained with N=64. At this level of fragmentation, the best threshold was also determined automatically by maximizing between-groups variance when luminance distribution was divided into two pixel groups, without achieving improvements in analysis. However, this last approach can work as the basis for a method which approximates an image histogram as the sum of two weighted normal distributions, one for background and one for roots.
KEYWORDS: minirhizotrons, image analysis, local thresholding, luminance distribution.

INTRODUCTIONS

Progress in root research is still hindered by the great complexity of minirhizotron root images, which slows development of completely automated procedures of analysis (Richner et al., 2000). The major critical step in analysis is root recognition. For this aim, the most frequently used technique is thresholding (global technique), which is less effective when roots share the same light intensity as non-root regions. A new automatic analytical procedure was set up on maize root images, taking into account operations of shade correction, linear stretching and image fragmentation.

METHODS

A sample of 40 maize root images taken from PVC minirhizotrons was used to calibrate the image analysis procedure. The images (600-DPI resolution, 24-bit TIFF format, 736×560 pixels), taken at the same positions on 7 observation dates from May to September, were processed by KS 300 software (Carl Zeiss, München, Germany). The blue band in the images was analysed (Vamerali et al., 1999), after shading correction with a “white” image (white paper covering the minirhizotron). The following procedure was applied to each area (rectangle) derived from 5 levels of image subdivision, i.e. 1 (entire image), 4, 16, 64, 256 sectors: i) removal of the whiter regions (water drops), ii) linear stretching of luminance histogram; iii) binarization at 11 threshold values from 100 to 200 (step 10). Further discrimination of roots against extraneous objects was performed with the length/width ratio and the elongation index (perimeter^2/area) of convex objects.

RESULTS AND DISCUSSION

The most suitable threshold level, found by maximizing the coefficient of determinations between automatic and actual root lengths, decreased with time (Table 1), meaning that progressive root browning makes root identification more difficult. Higher accuracy in measuring root length was obtained by performing independent analysis on areas derived from subdivision of the original images into 64 sectors (rectangles) (Figure 1), on all dates except 6 and 7 (Table 1). Non-uniform camera lighting and local variation of the root/background contrast in the frame may explain this improvement compared with handling the images without fragmentation.

Table 1 – Parameters of automatic image analysis procedures leading to maximum coefficients of determination.

Observation date	Luminance threshold	No. image sectors	Length/Width ratio	R^2
1 (1 June)	160	64	4.6	0.69
2 (15 June)	170	64	4.4	0.39
3 (29 June)	170	64	3.3	0.73
4 (17 July)	150	64	2.8	0.45
5 (1 August)	160	64	3.8	0.55
6 (16 August)	140	256	2.6	0.38
7 (8 September)	150	4	3.1	0.28

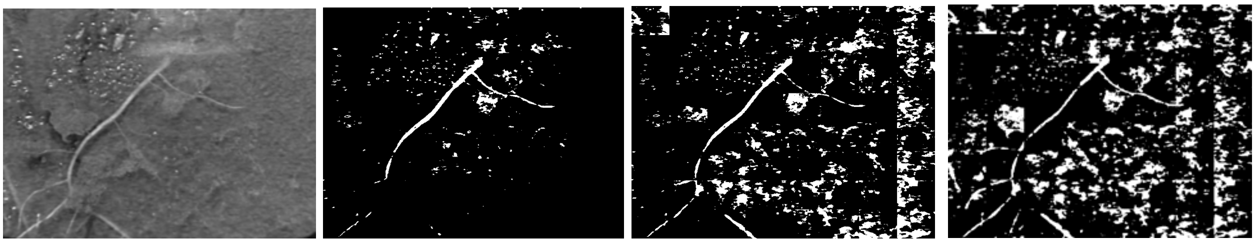

Figure 1 – Minirhizotron root image. From left: greyscale of blue band (a); fixed threshold applied to entire image (b) or 64 sub-areas separately (c); automatic threshold on 64 sub-images with bi-modal approximation (d).

After subdivision, the application of a simple linear stretching function led to local amplification of the luminance value range, making thresholding more effective. For high accuracy the most suitable threshold should be defined manually for each individual image (and/or rectangle), but our results indicate that a single threshold for the whole set of images can be picked up after initial calibration. In view of its laboriousness, this analysis may be performed automatically by adopting as threshold the gray value which maximizes between-group variance of luminance among all the possible couples of sub-histograms into which an image histogram may be split. This approach, although applied to single image sectors, did not further improve analytical performance. However, it was tested as a step in a different automatic threshold determination, made by approximating the frequency distribution of luminance in a single image fraction to the sum of two weighted normal distributions (background and roots). The threshold was taken as the mean value of root luminance $\pm k\sigma$, where σ is the standard deviation of root luminance and k an empirical coefficient. Although promising, this approach needs further calibration based on less or more evident bi-modality of sector histograms. The length/width ratio allowed better discrimination of roots than the elongation index of convex objects. The best values of this geometrical feature decreased from 4.6 to 2.6 (Table 1), and a general underestimation of root length occurred with increasing time/root age.

REFERENCES

Richner, W., et al., 2000. In *Root Methods – A Handbook*. Eds. Smit, A.L. et al., pp 304-341.
Vamerali, T., et al., 1999. An approach to minirhizotron root image analysis. *Plant Soil*, 217 (2/1), 183-193.