An automatic inter and intra-row weed detection in agronomic images

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Introduction

To quantify weed infestation from image an accurate crop/weed discrimination is required. Therefore it would be necessary to detect weed localized not only in the inter-row but also in the intra-row of crop. Hence, an image processing is required first in order to identify crop row frequency and second to determine the sowing pattern. Most of the authors have implemented methods for an inter-row weed detection (Tillett *et al* 2002; Vioix *et al* 2001, 2004) but few authors have reported intra-row weed detection algorithm. Astrand and Baerveldt (Astrand *et al* 2004) have developed an intra-row weed control based on the knowledge of the sowing pattern. The aim of this article is to propose an automatic weed infestation rate measurement based only on spatial information from synthetic images. An algorithm, based on a Fourier transform has been implemented and tested on simulated images of large view. This study on weed detection has been restricted for crop where seedling is done with precision seeder (like sunflower, sugar beet, corn ...). First this algorithm is able to determine automatically the spatial frequency and angle of the crop row. On a second hand, it is able to detect the crop plant individually. With these information weed detection can be easily achieved and compared with real infestation rate. The robustness of this method is investigated testing different parameters of simulated images (inter-row frequency, intra-row spacing, weed density).

1 - Crop row detection

Usually, from agronomic images, the segmentation between plants and soil can be easily done by lot of methods (Stewart and Tian 1999, Pérez *et al.* 2000, Yang *et al.* 2002). On this paper, we only present an algorithm for detecting crops in vegetation images.

Crops are sown in rows with a constant spacing depending of the species (15 cm for wheat, 45 cm for sugar beet, 70 cm for corn ...). On aerial images, these rows appear as parallel lines. Among the main line detection algorithms (Hough transform, linear regression, stripe analysis, Fourier transform) develop to detect parallel lines in images. The Fourier transform which gives information about repetitive structures, has been extensively applied and is particularly well adapted to characterize a crop row frequency (is the invert of the crop row spacing) and the orientation of the crop rows in images. Firstly, an easy threshold is done in Fourier space in order to only keep pixels which belong to the crop rows. Consequently, using this algorithm weeds in the inter row are well detected but weeds in the crop rows are not detected and identified as crops.

2 - Individual plant detection in crop rows

Various crops (corn, sunflower, sugar beet ...) are sown with a constant spacing between two plants in the same row. However, the seedling is not done on a grid. The origin of the sowing pattern of each crop row is not constant due the seeder mechanism. Due to this origin shift, a simple Fourier transform can not be used to detect the crop plant position in image.

Then, for each crop row, a mono-dimensional Fourier transform is computed. The maximum of this Fourier transform is the crop plant frequency. A threshold of the Fourier transform keeps the pixels which belong to the repetitive structures (i.e. the crop plants). A crop image is then deduced applying the logical operator “and” between these results and the ones of the previous method. Pixels which belong to crop row and to crop plant are classified as crop. Other pixels are classified as weeds. During evaluation procedure, we create two weed classes: inter-row weeds and intra-row weeds in order to evaluate the benefit of this method.

3 – Results

3.1 – Synthetic images

They are composed of three kinds of plants: crops, weeds in crop row and weeds in the inter-rows. We use these images in order to measure the accuracy of the weed detection algorithm. These images, as observed on the illustration 1, are build to be as realistic as possible using a random size (8 different sizes) and a random orientation (8 different orientations) for plants. Various parameters are used to characterize theses images:

- p_{crops} the period of the crop rows,
- p_{plants} the space between two crop plants of the same row,
- φ a random value for each crop row, corresponding to an offset along the crop row (φ varies from 0 to p_{plants}),
- θ this angle is the orientation of the crop rows,
- r_{inter} the weed rate in the inter row,

- r_{intra} the weed rate in the crop rows.

Size of the plants depends on p_{crops} in order to simulated resolution of the images. Two rules are used to keep a realistic simulation:

- p_{crops} is always greater than p_{plants}
- r_{inter} is always greater than r_{intra}

Illustration 1: Source image

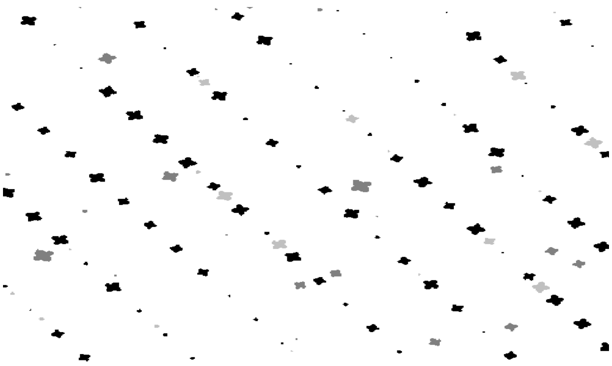

Illustration 2: Reference image (crops in black, weeds in the inter rows in dark grey, weeds in the rows in light grey)

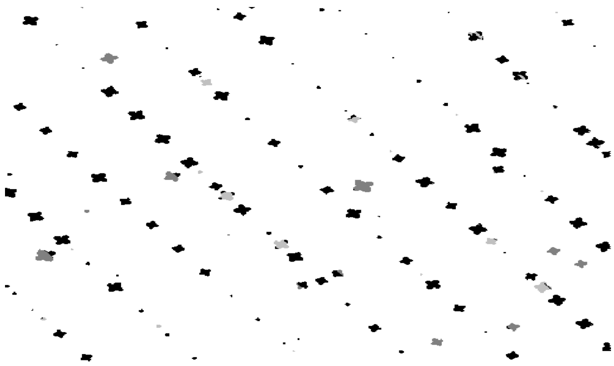

Illustration 3: Result image (same colors as previous)

The weed detection algorithm has been applied on the source Image (illustration 1). Illustration 3 presents the result image and table 1 the real and measured values. It is observed that the measured angle and the crop frequency detected and weed rates are very close to their real values. Most of the plants are well classified and only some leaf extremities or small plants close to crop plants are misclassificated.

Table 1: Parameters used for simulation and results

Parameter	***Real value***	***Measured value***
p_{crops}	75 pixels	76.34 pixels

Parameter	*Real value*	*Measured value*
p_{plants}	40 pixels	N.A.[1]
θ	34°	33.98°
r_{total}	0.2802	0.2106
r_{inter}	0.1593	0.1218
r_{intra}	0.1209	0.0888

3.2 – Accuracy of geometrical parameters

First, the accuracy of the parameters of crops (crop row frequency and crop row angle) is measured. The quality of the crop plant detection is directly determined by the quality of the measurement of these two parameters. In order to evaluate the quality of these measurements, a huge set (more than 1000 images) of simulated vegetation images was used. This set was split into 15 groups of 75 images respectively. Table 2 presents the bounds of these parameters during evaluation.

The following results are extracted for one of these groups. Measured frequency and angle are compared with theoretical values as shown in illustrations 4 and 5. The mean absolute error for the measured frequency is 0.0013 (frequency in image is always bounded by 0 and 1). For, the measured angle, the mean absolute error is 0.4672.

Table 2: Parameters used for simulation

Parameter	*Min value*	*Max value*
p_{crops}	20 pixels	120 pixels
p_{plants}	20 pixels	120 pixels
θ	0	90°
r_{inter}	0	0.25
r_{intra}	0	0.25

1 The measured value of the plant period is not noticed, because a value is measured for each crop rows.

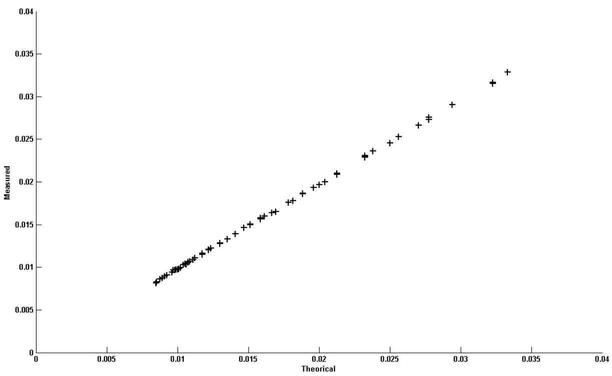

Illustration 4: Measured frequency vs. real frequency

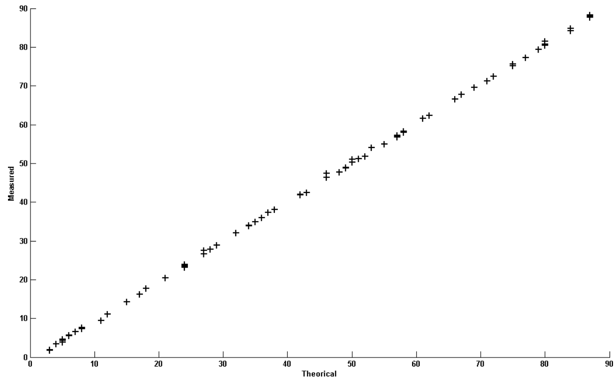

Illustration 5: Measured angle vs. real angle

3.3 – Improvement of weed detection using crop plant detection

In order to estimate the quality of the algorithm we define 3 weed rates. The intra row weed rate is the ration between the number of pixels of weeds in the row and the total number of plants (N). The inter row weed rate, is the ration between the number of pixels in the inter-row and N. The total weed rate is the sum of these two ratios.

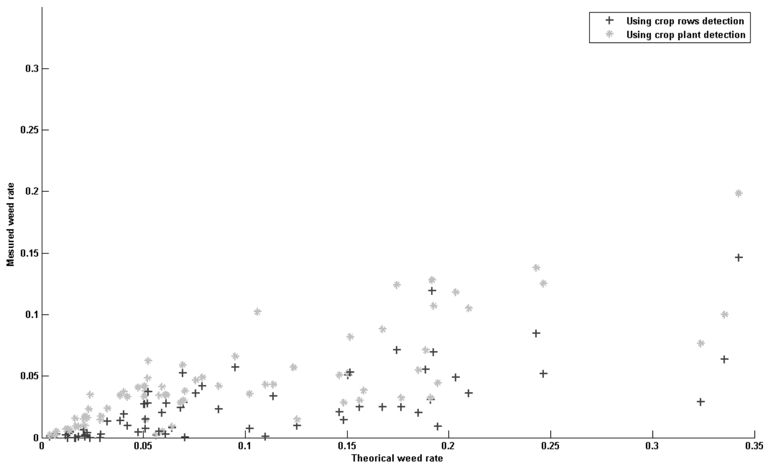

Illustration 6: Measured rate vs. real rate

From the synthetic images, it is very simple to compute the real value of these rates. With these three rates we can evaluate the benefit of the crop plant detection. Illustration 6 shows the total measured rate compared to the total theoretical rate. Dark cross (+) are the weed rate computed with only the inter row weed detection, grey stars (*) show the weed rate computed using the inter row weed detection and the crop plant detection. This method leads to a best approximation of the real total weed rate.

In order to explain limitations of the weed detection algorithm, we compare the measured values of the two weed rates (inter row and intra row) with their real values (illustrations 7 and 8). The crop row detection is efficient for various weed rates. However, the measured rate is lower than the real rate because some leaf extremities of weeds are not detected. This often occurs for weeds near crop rows.

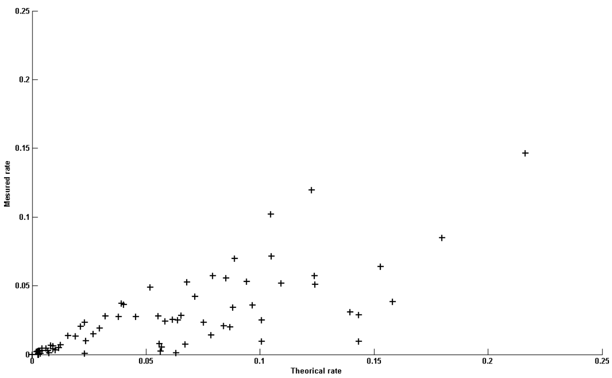

Illustration 7: Measured inter row weed rate vs. real inter row weed rate

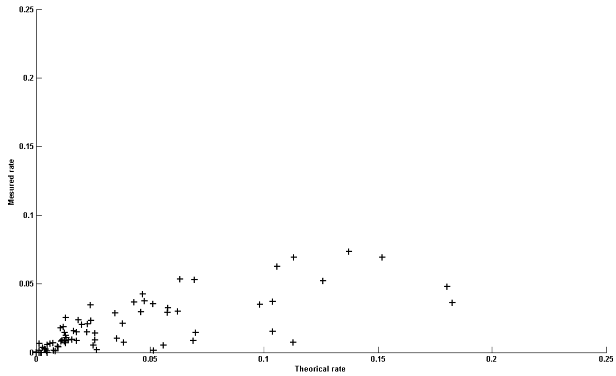

Illustration 8: Measured intra row weed rate vs. real intra row weed rate

Conclusion

An automatic weed detection algorithm based on a simple fast Fourier transform has been successfully validated using simulated images. Many parameters have been tested in order to simulate various cases and to demonstrate the robustness of this method. Currently, this algorithm is applied on aerial sunflower images shot from a multispectal imaging system embedded in an aircraft where a weed infestation rate has to be determined.

References

Åstrand B., Baerveldt A. -J. (2004): Plant recognition and localization using context information- In: *Proceedings of Mechatronics & Robotics Conference* – special session Autonomous Machines in Agriculture, Aachen, Germany, September 13-15 2004, pp. 1191-1196.

Pérez A.J., Lopez F., Benloch J.V., Christensen S. (2000): Colour and Shape Analysis Techniques for Weed Detection in Cereal Fields – Computers and Electronics in Agriculture, Vol N°25, pp. 197-212

Steward B.L., Tian L.F. (1999): Machine-Vision Weed Density Estimation for Real-Time, Outdoor Lighting Conditions – Transactions of the ASAE, Vol 42(6), pp 1897-1909

Tillet N.D., Hague T., Miles S.J. (2002): Inter-row vision guidance for mechanical weed control in sugar beet – Computers and Electronics in Agriculture, Vol N°33, pp.163-177.

Vioix J.-B., Douzals J.-P., Truchetet F., Assémat L., Le Corre V., Dessaint F., Guillemin J.-P. (2001): Development of a Spatial Method for Weed Detection and Localization – In: *International Conference on Quality Control by Artificial Vision*, Le Creusot, 2001

Vioix JB., Douzals JP., Truchetet F. (2004): Aerial detection and localization of weed by using multispectral and spatial approaches – In: *Proceedings of AgEng2004, European Society of Agricultural Engineers*, Leuven, Belgium, September 12-16 2004.

Yang C.C., Prasher S.O., Landry J., Ramasway H.S. (2002): Development of Neural Networks for Weed Recognition in Corn Fields – Transaction of the ASAE, Vol 45(3), pp. 859-864