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Detecting crops and weeds in precision agriculture

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The spatial distribution of weeds can be mapped from digitally recorded images and used to target the application of herbicides.

In recent decades, precision agriculture, a practice geared to delivering 'the right dose at the right place at the right moment,' has become possible with the development of remote sensors. In particular, spatial vegetative heterogeneity within fields can be digitally recorded using vision systems embedded either in agricultural engines or in small remotely piloted aircraft. These images can then be used to identify regions of high weed content to focus, and reduce, herbicide applications. We previously developed two programs based on such systems for weed detection in crop fields.

A multispectral camera embedded in an aircraft (see Figure 1) enabled us to obtain images within which the spatial distribution of weeds can be estimated. Various classification methods (ANN, *k*-nearest neighbor) were used to categorize pixels as either crop or weed.[1,2] Alternatively, the second experimental system incorporates an imaging system in a real-time precision sprayer (see Figure 2). For instance, from a monochrome CCD camera located in front of the tractor, the discrimination between crops and weeds is obtained using a 2D Gabor filtering process based on spatial information.[3] This method allows us to generate a weed infestation map under the assumption that the periodic signal is associated with crop rows. A pinhole camera model is then used to translate the weed patch coordinates from the image into real-world coordinates to time the triggering of a series of actuators fixed in front of each nozzle on the spraying boom.
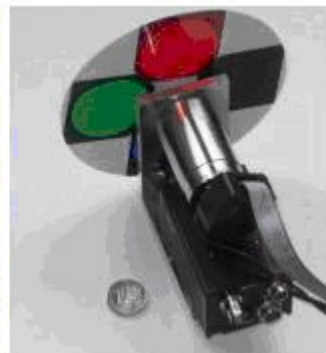

Figure 1. A four filter wheel camera with filters in the blue, green, red and infrared ranges is embedded in a small remotely piloted aircraft.

However, few manual ground assessments have been done to evaluate the performance of these image-processing techniques. Hence, a method to validate the potential of such crop/weed discrimination algorithms is needed. When the initial parameters of the scene (crop and weed locations, weed infestation rates) are known, it is possible to assess and compare the efficiency of crop/weed discrimination algorithms such as Gabor filtering, the Hough transform, and the wavelet transform.

Figure 2. The real-time precision sprayer. Actuators are placed in front of each nozzle of the spraying boom and are activated according to the speed sensor and the image snapped by a camera mounted in front of the tractor.

First, a two-dimensional virtual agronomic image was created in simulation software using a statistical approach that models the spatial distribution of plants.[4,5] In this field, a periodically arranged sowing pattern is chosen to model the crop plants. The design of this pattern mimics either monocotyledonous or dicotyledonous plants: see Figure 3(a). The weed plants are positioned by applying a mixture of two different stochastic processes (Poisson and Neymann–Scott) to model uniform or patchy distributions. Discrete statistics have been developed under the assumption that weed spatial distribution is a random process and with no memory between successive events (two built images). Moreover, as crop fields typically have few weeds, we have set the occurrence of weed plants relative to crops to very low. In this model, the initial inter-row weed infestation rate (WIR) is a parameter defined as:

$$\text{initial WIR}_{\text{inter-row}}(\%) = \frac{\text{inter-row weed pixels} \times 100}{(\text{crop} + \text{inter-row weed})\text{pixels}}$$

Next, a virtual camera with predefined intrinsic (CCD size, focal length, and distortion) and extrinsic (translation and rotation) parameters is located in the field, and a snapshot is taken of this virtual field. From a projective transformation (pinhole camera model) a black-and-white virtual image can be obtained: see Figure 3(b). This image can then be used in place of an actual image of a crop field to test the efficiency of crop/weed discrimination algorithms.

This method provides a useful tool to evaluate the robustness of spatial discrimination algorithms. The method has been developed to assure easy algorithm integration and can be configured to test multiple experimental designs. We are now interested in applying the method to test new discrimination algorithms and are working to expand the functionality of the model through the addition of other parameters. In particular, we are interested in exploring the use of spectral data to further discriminate crops from weeds.
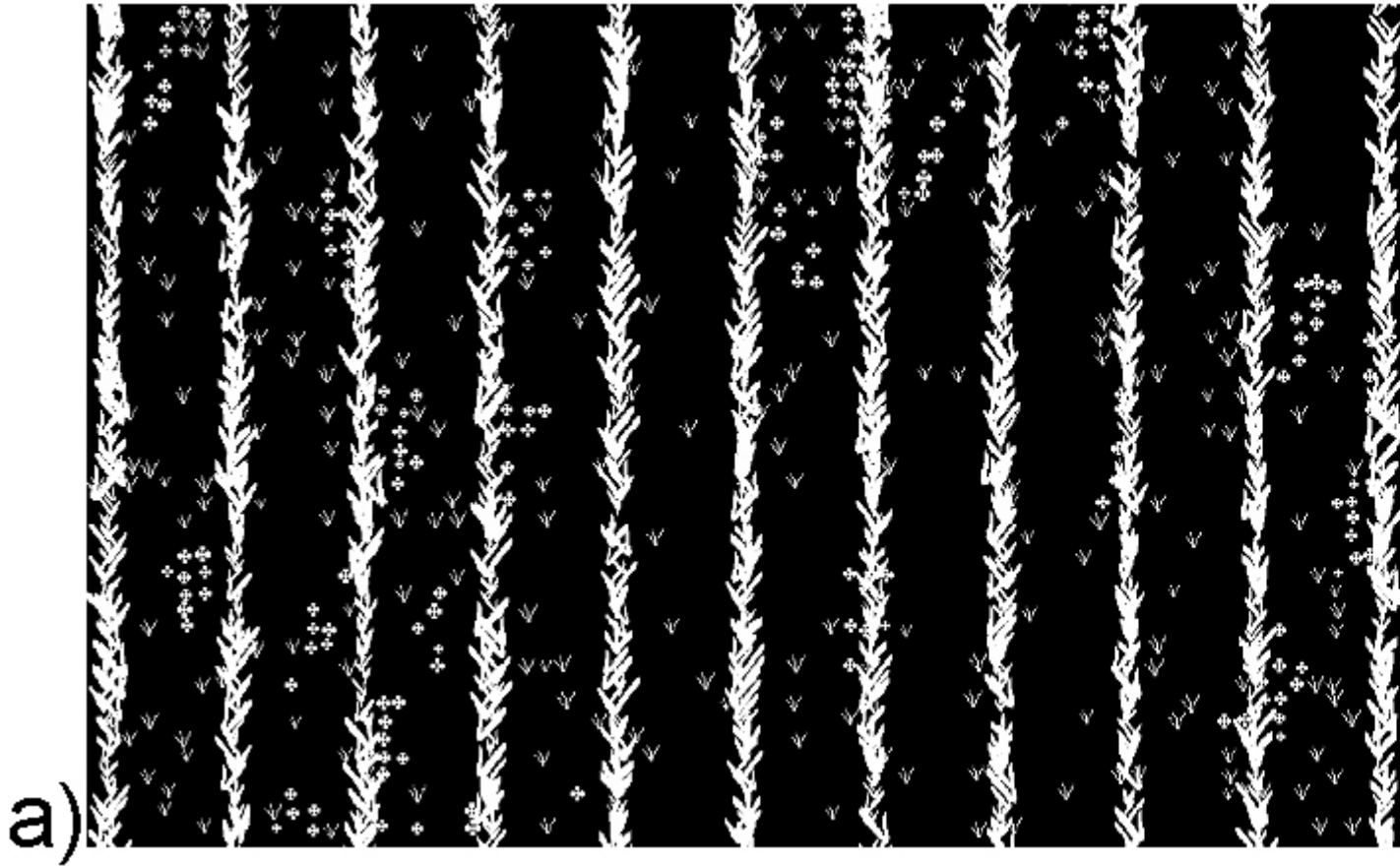
Figure 3. (a) A virtual wheat field with a mixture of both uniform and patchy weed spatial distributions (WIR =20%). (b) Resultant virtual wheat field picture: inter-row width =16cm, camera height = 1.20m, pitch angle = 65°, and WIR = 20%.

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References:
1. J. B. Vioix, J. P. Douzals, F. Truchetet, L. Assemat, J. P. Guillemin, Spatial and spectral methods for weed detection and localization, *Eurasip J. Appl. Signal Process.* 7, pp. 679-685, 2002.
2. J. B. Vioix, J. P. Douzals, F. Truchetet, Development of a multispectral imagery device devoted to weed detection, *J. Electron. Imag.* 13, no. 3, pp. 547-552, 2004.
3. J. Bossu, C. Gée, F. Truchetet, Development of a machine vision system for a real time precision sprayer, *Proc. SPIE* 6356, pp. 63560K, 2007.
4. G. Jones, C. Gée, F. Truchetet, Crop/weed discrimination in synthetic agronomic images, *Proc. SPIE* 6497, pp. 64970E, 2007.
5. G. Jones, C. Gée, F. Truchetet, Simulation of agronomic images for an automatic evaluation of crop/weed discrimination algorithm accuracy, *Proc. SPIE* 6356, pp. 63560J, 2007.