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Automatic expert system for weeds/crops identification in images from maize fields

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ABSTRACT

Automation for the identification of plants, based on imaging sensors, in agricultural crops represents an important challenge. In maize fields, site-specific treatments, with chemical products or mechanical manipulations, can be applied for weeds elimination. This requires the identification of weeds and crop plants. Sometimes these plants appear impregnated by materials coming from the soil (particularly clays). This appears when the field is irrigated or after rain, particularly when the water falls with some force. This makes traditional approaches based on images greenness identification fail under such situations. Indeed, most pixels belonging to plants, but impregnated, are misidentified as soil pixels because they have lost their natural greenness. This loss of greenness also occurs after treatment when weeds have begun the process of death. To correctly identify all plants, independently of the loss of greenness, we design an automatic expert system based on image segmentation procedures. The performance of this method is verified favorably.

1. Introduction

1.1. Problem statement

Machine vision is an excellent sensor, which is being currently incorporated in autonomous tractors, for treatments over site-specific areas in a larger field (Davies, Casady, & Massey, 1998). Focusing on maize fields, one of the most important treatments is weeds killing, where plants (weeds and crops) must be identified as a previous step. Different methods and strategies for plant identification have been applied in different works (Burgos-Artizzu, Ribeiro, Tellaeche, Pajares, & Fernández-Quintanilla, 2009; Guerrero, Pajares, Montalvo, Romeo, & Guijarro, 2012; Guijarro et al., 2011; Montalvo et al., 2012; Onyango & Marchant, 2003; Tellaeche, Burgos-Artizzu, Pajares, & Ribeiro, 2008b; Tellaeche, Burgos-Artizzu, Pajares, Ribeiro, & Fernández-Quintanilla, 2008a). López-Granados (2011) makes a revision of methods where plant identification is a key step in the process. Most existing strategies address the problem of green identification under the assumption that plants display a high degree of greenness, but they do not consider the fact that plants may have lost their degree of greenness for different reasons.

Indeed, maize is an irrigated crop, which is also unprotected from the rainfall. When the layer of water is abundant or its fall on the ground is relatively strong, soil materials (particularly clays) impregnate the vegetative cover, particularly those parts close or near to the soil. In this case, the green spectral component of pixels belonging to the plants is masked by the dominant red spectral component coming from materials existing in the soil; Fig. 1 displays an image where this appears clearly in the middle central part of the image and also at the ends of the leaves in the maize that are oriented toward the soil. Fig. 2 displays similar occurrences at the bottom part (center and right). This makes methods based exclusively on the greenness identification, i.e. plant coverage based on the computation of vegetation indices, fail under such situations. Indeed, soil and masked plants are both identified as soil.

In Guerrero et al. (2012) we have already addressed this problem by applying a learning approach based on support vector machines. As all learning strategies, this method requires a training phase where samples are conveniently provided for estimating the required parameters (support vectors), and then the posterior decision phase is highly dependent of the samples supplied, i.e. from the images which have been used for training. Moreover, the learning phase requires a certain number of images previously selected.

We propose a new automatic method based on several sequential stages, where the linking of these stages and the image segmentation processes, applied at each stage, are based on the application of the human expert knowledge. This leads to the design of the proposed expert system, gaining an important advantage with regard to the one described in Guerrero et al. (2012) because no training is required and it can be directly applied to the unique image under processing becoming independent from

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Fig. 1. Original image where weeds in the middle central part appear masked.

Fig. 2. Original image where weeds in the bottom central and right part appear masked.

other images, which are to be selected. One of the processes involved into two different stages is image thresholding, based on the Otsu's method, which is self-adjustable, dealing well with images captured under different conditions such as sunny or cloudy days, affecting illumination variability, (Tian & Slaughter, 1998); they are typical situations in agricultural images coming from outdoor environments. The design of this automatic expert system makes the main contribution of this paper.

Additionally, because this system is designed to identify plants that have lost the greenness, it can be applied to evaluate the treatment effectiveness. Indeed, as mentioned before, some site-specific

Fig. 3. Original image captured after the application of herbicide two days ago (weeds in the central inter crop rows are evolving to a dry stage). The field has also received direct rainfall.

treatments are intended to kill weeds in maize crops, when weeds are in the dying process, before reaching dry completely; they also have lost their greenness, compared to their healthy state. The proposed expert system can be used for identifying such plants and hence the treatment effectiveness.

Fig. 3 displays at its central inter-row crop, weeds evolving toward a dry stage after the chemical treatment with herbicide applied two days ago. This image has also received direct rainfall and some parts are impregnated with materials coming from the soil as before.

1.2. Revision of methods

Several strategies have been proposed for segmenting crop canopy images, specifically oriented towards green segmentation:

(1) Visible spectral-index based, including the excess green index (ExG, Ribeiro A., Barroso J., & M. C., 2005; Woebbecke, Meyer, von Bargen, & Mortensen, 1995), the excess red index (ExR, Meyer, Hindman, & Lakshmi, 1998), the color index of vegetation extraction (CIVE, Kataoka, Kaneko, Okamoto, & Hata, 2003), the excess green minus excess red index (ExGR, Neto, 2004) and the vegetative index (VEG) described in Hague, Tillet, and Wheeler (2006), which is designed to cope with the variability of natural daylight illumination. ExG, ExGR, CIVE and VEG have been applied under a combined form in Guijarro et al. (2011) gaining in performance with respect to their individual application. All these approaches need to fix a threshold for final segmentation, i.e. to discriminate between plants and other parts (soil, sky).

(2) Specific threshold-based approaches, including dynamic thresholding. Generally, these techniques assume a two-class problem where plants and soil are to be identified. Reid and Searcy (1987) estimate a decision function under the assumption that the classes follow Gaussian distributions. The Otsu's method (Otsu, 1979) is also applied considering a bi-class problem (Ling & Ruzhitsky, 1996; Shrestha, Steward, & Birrell, 2004). These algorithms are applied to gray images. Gebhardt, Schellberg, Lock, and Kaühbauch (2006) apply also thresholding for segmentation transforming the images from RGB to gray scale intensity. This algorithm was later improved using local homogeneity and morphological operations in Gebhardt and Kaühbauch (2007). Kirk, Andersen, Thomsen, and Jørgensen (2009) apply a combination of greenness and intensity derived from the red and green spectral bands and compute an automatic threshold for a two-class problem assuming two Gaussian probability density functions associated to soil and vegetation respectively; this procedure requires the previous estimation of an angle to rotate the hypothetical greenness axis. Meyer and Camargo-Neto (2008) have applied the automatic Otsu's thresholding method for binarizing ExG and the normalized difference index (NDI), where a comparison is established against the segmentation obtained from ExGR determining that in this last case, a value of zero suffices for the threshold, therefore the Otsu's method is not required. Guijarro et al. (2011) and Burgos-Artizzu, Ribeiro, Guijarro, and Pajares (2011) have applied the statistical mean value of the transformed image obtained with the vegetation indices instead of automatic thresholding such as Otsu. They justify its choice because Otsu's method gives a threshold value higher than the mean and produces infra-segmentation, i.e. some plants are not conveniently identified.

(3) Learning-based, Meyer, Camargo-Neto, Jones, and Hindman (2004) have applied unsupervised approaches, including fuzzy clustering, for segmenting regions of interest from