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Research Paper

Machine vision system for the automatic segmentation of plants under different lighting conditions

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Precision agriculture needs the use new technologies for identification. Using digital images and analysing their colour is one of the most useful methods for the segmentation of plants from their background and is a basic operation in all machine vision applications. A machine vision system is presented based on hybrid artificial neural network-harmony search (ANN-HS) classifiers for the segmentation of different plants in different growth stages, different conditions of the day and one controlled state and different imaging situations. This system works in two stages; the first stage is to specify photography state and the second stage is to apply an appropriate threshold. In total, 23,899 images were taken from eight different states during the day and one control state. Five features among 126 extracting features of five colour spaces RGB, CMY, HSI, HSV, YIQ and YCbCr for use in classification unit were selected using hybrid artificial neural network – differential evolution algorithm. Meta-heuristics and statistical classifiers were used for classification. The results showed that the accuracies of meta-heuristics method of the hybrid artificial neural network-harmony search and k-nearest neighbour statistical method were 99.69% and 94.06% respectively. In order to determine appropriate thresholds an improved YCbCr colour space was proposed. The results showed that among eight different states during day and one control state, the level of threshold for six states must be determined in third channel related to this colour space and the rest should be determined in HSV and YIQ colour spaces. The suggested machine vision system segments each image during 0.37 s. Finally, it can be claimed that this system is applicable in all machine vision systems related to fields and has high accuracy and speed.

1. Introduction

With increasing population and the occurrence of successive droughts in many parts of the world, many governments are urging the implementation of precision agriculture. The term of precision agriculture can have different definitions based on different goals. But generally, the set of actions that causes maximum exploitation of agricultural land and/or the optimal use of inputs is called precision agriculture. Using modern

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Nomenclature

LED	Light emitting diode
CMOS	Complementary metal oxide semiconductor
R	The first component of RGB colour space
G	The second component of RGB colour space
B	The third component of RGB colour space
C	The first component of CMY colour space
M	The second component of CMY colour space
Y	The third component of CMY colour space
H	The first component of HSI colour space
S	The second component of HSI colour space
I	The third component of HSI colour space
R_n	First element of normalised RGB
G_n	Second element of normalised RGB
B_n	Third element of normalised RGB
Grey	Grey channel
ROC	Receiver operating characteristic
FN	False Negative
KNN	K-nearest neighbour
ExG	Excess green
ExR	Excess red
CIVE	Colour index for vegetation extraction
EXGR	Subtracting excess green and excess red parameters
NDI	Normalised difference index
GB	Green minus blue index
RBI	Red Blue contrast
ERI	Excess Red Index
EGI	Excess Blue Index
EBI	Excess Blue Index
ANN-GA	Hybrid artificial neural network-genetic algorithm
ANN-DA	Hybrid artificial neural network-differential evolution algorithm
ANN-PSO	Hybrid artificial neural network-particle swarm algorithm
ANN-HS	Hybrid artificial neural network-harmony search
TN	True Negative
TP	True Positive
FP	False Positive

methods and technologies such as image processing, video processing, artificial intelligence and machine vision is essential for implementing precision agriculture. Among the applications of machine vision in agriculture are the optimum application of pesticides (Lomotey, Chai, Ahmed, & Deters, 2013), optimum spraying of herbicides (Bossu, Gee, & Truchetet, 2008; Hamuda, Glavin, & Jones, 2016; Hlaing & Khaing, 2014; Tang, Chen, Miao, & Wang, 2016), accurate estimation of nitrogen level in a crop (Intaravanne & Sumriddetchkajorn, 2012), determination of crop growth stage (Kataoka, Kaneko, Okamoto, & Hata, 2003), calculation of solar radiation received by crop (Molina-Martínez, Jiménez, Ruiz-Canales, & Fernández-Pacheco, 2011), identification of plants diseases (Camargo & Smith, 2009) and identification of fruits (Liu et al., 2016). The most important section in designing machine vision systems is segmentation as this operation concerns feature extraction and classification of identified objects (a set of connected pixels is defined as an object). There are in total three basic methods of segmentation; colour, edge, and area-based methods (Sonka, Hlavac, & Boyle, 1999, p. 555; Sun, 2000; Teimouri, Omid, Mollazade, & Rajabipour, 2014). Edge and area based methods are not easily applied for natural field conditions since direct radiation from the sun results in different images and frames from field with very high pixels in sunny areas and very low pixels in shadows and this can cause misidentification since identifying the area and edge is based on a sudden change of pixels intensity. Font et al. (2015) overcame this problem by using artificial illumination at night but under daylight conditions different researchers such as Lee and Archibald (2010), Mollazade, Omid, and Arefi (2012) and Mery, Pedreschi, and Soto (2013) performed segmentation of green colour plants from their background using colour thresholds. Hernández-Hernández et al. (2016) also proposed a machine vision system based on the hypothesis that non-conventional factors such as shadow, pixel saturation, noise, light changes and essential parameters of camera should not affect segmentation. For this reason, their suggested system was able to select appropriate colour space based on the lighting conditions governing the field. Therefore, they suggested a method based on a teaching colour model based on different colour spaces in order to segment green colour plants from soil. The colour models used in their study were RGB, HSL, YCbCr, YUV, L*a*b*, L*u*v*, TSL, I1I2I3 and XYZ. The images were taken in four different states of under direct sunlight, cloud and two types of different white balance of the camera. The crops used in their study were Lettuce (var. Iron), Lettuce (var. Little gem) and Kohlrabi (var. Gongylodes). In order to present the model, 182 images were taken and different models were presented using the probabilistic classifier with Gaussian models, artificial neural networks, decision tree, support vector machine, ADA boost (combination of simple classifiers), expectation/maximisation algorithm and k-nearest neighbours. The results showed that the suggested method had proper efficiency. However, the suggested method was not able to segment in all lighting conditions because of two reasons: 1 – variable light intensity during day and since their suggested system was only designed on two intensity states, it did not have general application. 2 – The database was small; databases should include all conditions for designing a machine vision system. In further research, Liu et al. (2016) designed a machine vision system for segmenting apple based on colour and position data. This system performed segmentation based on artificial light with less illumination. The suggested method had two main steps: the first step included training an artificial neural network using RGB and HSI colour space elements and finally presenting a model for segmenting apple fruits. This stage performed segmentation action incorrectly because of shadows in some parts of the apple (i.e. non-uniform brightness). For this reason, in order to complete segmentation, a second step was added that considered the colour and pixels around the segmented area. Twenty apple fruits were used in their study. The results showed that the suggested system had acceptable results in the segmentation of these apples. However, the interesting point is that retraining of artificial neural network