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A robust algorithm based on color features for grape cluster segmentation

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ABSTRACT

Image processing has been widely used for automation purposes in modern agriculture. The algorithm development for the image segmentation is the most controversial and challenging issue in orchard environment which researchers encounter. This paper describes a robust algorithm based on artificial neural network (ANN) and genetic algorithm (GA) for segmenting grape clusters from leaves and background using color features near to harvest. GA was employed for optimizing of ANN structure and selecting supreme color features simultaneously. The results showed that GA specifies the 8 color features as supreme features and define 8–15–35–3 as the best structure of the ANN. The overall accuracy of the algorithm was 99.40%. The promising results in algorithm development described in this study lead to introduce it as a practical sensing tool in precision agriculture as well as those industrial facilities dealing with image analysis.

1. Introduction

There are several studies in the literature where image analysis has been applied to detect agricultural products. Mora et al. (2016) proposed an image segmentation algorithm to exclude contributions of non-leaf materials from leaf material in the analysis. Shapiro et al. (2009) and Steward et al. (2002) developed an image processing algorithm to detect the date palm and weed targets, respectively and obtained results were used for further operations. Amatya et al. (2015) investigated the image processing algorithm to branch detection for cherry harvesting. They used Bayesian classifier and R, G and B color features of each pixel for segmenting branch pixels and achieved 89.6% branch pixel classification accuracy.

Color features have been used for red and green apple recognition by Zhou et al. (2012). Their results showed that color difference features (R-G, R-B, G-R, and R-G) had good potential for segmentation of apple fruits form background (leaves, branches, and sky). Another study was carried out on apple identification based on color and shape features in order to estimate crop-load (Gongal et al., 2016). Grayscale images were obtained by subtracting green and blue channels from red channel (R-G and R-B). Then Otsu's threshold method was used to convert the gray images to binary images. Canny edge detector was carried out to detect edge and Circular Hough Transformation (CHT) was applied to identify circular objects that are likely to be apples. The apple identification accuracy was 79.8% in their study.

Diago et al. (2012) were developed an approach by generating a supervised classifier based on the Mahalanobis distance to characterize the grapevine canopy, and assessed leaf area and yield using RGB images. The segmentation algorithm was able to distinguish the leaves with 92% and grape cluster with 98% accuracy. The ability to segment was depended on the contrast between black grapes with leaves and background. Berenstein et al. (2010) developed an image processing algorithm for detection of grape cluster based on Pearson's correlation method for deleting the effective features and a decision tree algorithm for classification. Their obtains showed that mean gradient magnitude of the R, G, B and V channels were supreme features for segmenting the grape cluster area from foliage area. Also, they found that grape cluster detection leads to 30% reduction in use of pesticides. Nuske et al. (2014) presented the image processing technique for yield estimation in the vineyard. Their results demonstrated that color features and texture-descriptors worked very well in different light conditions for grape cluster segmentation. In addition, results indicated that total yield could be estimated with an average error between 3% and 11%.

Artificial neural network (ANN) and genetic algorithm (GA) and their combination have shown to be powerful tools for solving the complex problem that has not exact solutions especially in image segmentation area (Al-Mohair et al., 2015; Khan and Jaffar, 2015).

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Important steps in improving the performance of the ANN classifier are to find the best structure of the ANN and select the best features used as input to the ANN for classification. The ANN structure has two major parameters: number of hidden layers and neurons in each hidden layers and one of the common methods used by authors for finding the best structure is train and error method (Salehi et al., 2011; Behroozi-khazaei et al., 2013). Selecting the best features for classification means that those features that do not help to improve the classification accuracy should be removed from the feature vector. Nevertheless, an effective feature vector must contain sufficient elements for classification (Omid et al., 2010; Banakar et al., 2017). Appling the soft computing method such as GA for finding the best structure of the ANN and best features selection is interesting and growing.

The GA was already used for optimizing the ANN structure (Mohebbi et al., 2011) and for feature selection (Vafai and De Jong, 1992; Chtioui et al., 1998). The feed-forward neural networks are also the most popular architectures due to flexibility architecture and good representational capabilities (Salehi et al., 2011). Liu et al. (2016) performed the ANN technique for on-tree recognition of apple at nighttime for apple harvesting robots. The ANN has adopted a classical topological structure with 3 layers and the number of nodes in hidden layer was determined by an empirical formula. The color components of RGB and HSI are used as input data for ANN. Also for better segmenting of regions around the edge of apples, the color difference between recognized regions and edge (R1–R2, G1–G2, B1–B2) and the distance of them are extracted which is applied as input data of the second ANN. Their results indicated that proposed algorithm worked very well for apple segmenting with 97% accuracy. Furthermore, Zheng (2005) developed an algorithm for tree crown detection based on ANNs. The tree crown features were extracted after image segmentation. These features were put into the designed ANN, and six unknown typical tree crowns (cone, oval, spherical, cylindrical, umbellate, and truncate) recognized precisely and effectively. No quantitative results were found. Cheng et al. (2017) were developed the new approach of using image analysis and tree canopy features to predict the first reliable time of yield (early yield) with ANN. For each canopy image, pixels were segmented into fruit, foliage, and background using image segmentation. The four features extracted from the image data set: total cross-sectional area of fruits, fruit number, total cross-section area of small fruits, and cross-sectional area of foliage that were used as inputs and actual weighted yield per tree was used as output. The results showed that correlation coefficients (R2) between the estimated and the actual weighted yield, mean forecast error (MFE) measures the unbiasedness between the estimated and the actual weighted yield, mean absolute percentage error (MAPE), and root mean square error (RMSE) were 0.81, −0.05, 10.7%, 2.34 kg/tree, respectively.

As mentioned earlier, image processing has been used to assist with precision agriculture practices specially yield estimation. On the other hand, Gongal et al. (2015) were reported that one of the issues which can increase the overall accuracy of fruit detection is the improvement of image segmentation method. While the fruit segmentation is the issue when the green/greenish fruits are surrounded by green leaves, a color segmentation method is not an easy task. Therefore, a robust algorithm is needed for fruit detection with high accuracy regardless of fruit color and application environment. The objective of this study was to present a

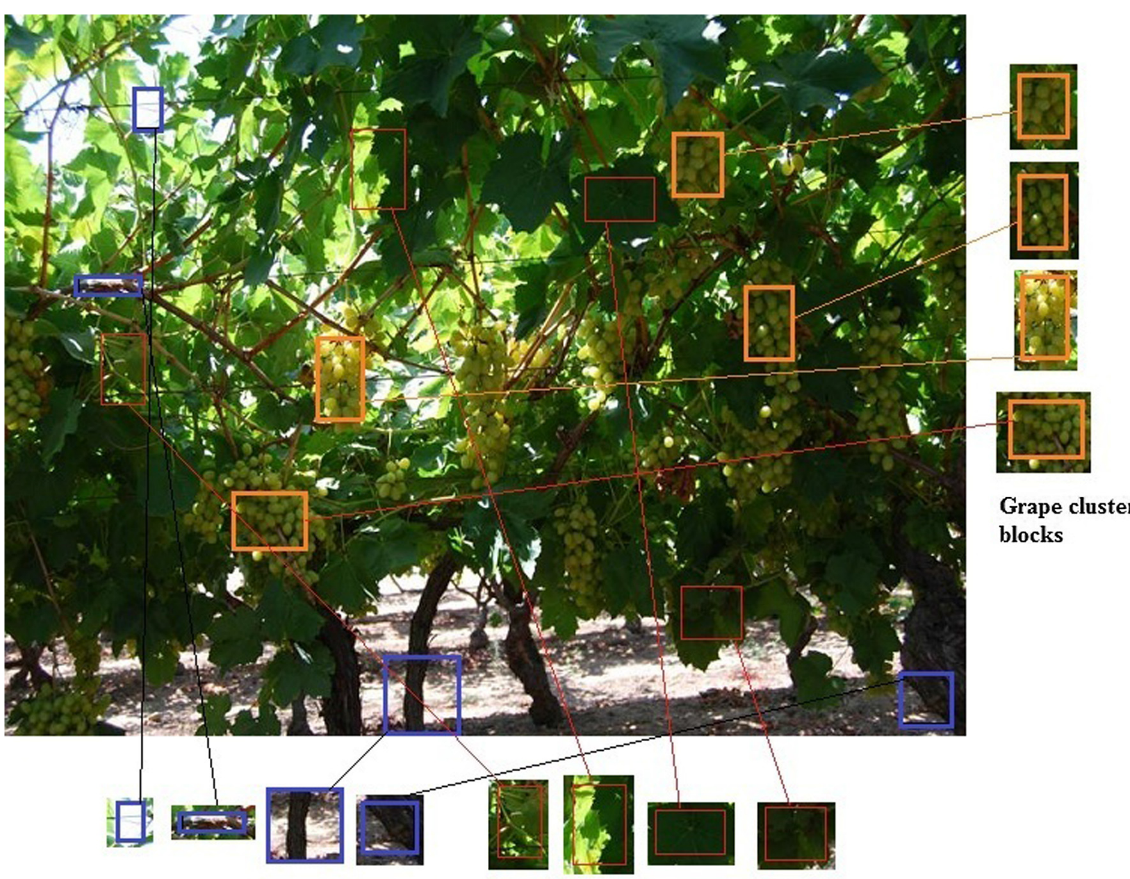

Fig. 1. The blocks of grape clusters, leaves, and other subjects.