Computers in Industry 98 (2018) 80–89

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

A fast and accurate expert system for weed identification in potato crops using metaheuristic algorithms

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ARTICLE INFO

Article history:
Received 21 June 2017
Received in revised form 28 February 2018
Accepted 2 March 2018
Available online xxx

Keywords:
Agricultural expert systems
Computer vision
Weed control
Cultural algorithm
Harmony search

ABSTRACT

Precision Agriculture is an area that can benefit from the latest advances in expert systems. One of the goals is to detect and remove weeds intelligently, so that herbicides are only sprayed in areas where weeds exist. By reducing the amount of herbicides used, the risk of contamination of crop and water resources is avoided, which could produce harmful environmental effects. In this paper, a new computer vision based expert system is presented for identifying potato plants and three different kinds of weeds (*Secale cereale* L., *Polygonum aviculare* L. and *Xanthium strumarium* L.) in order to perform site-specific spraying. The videos were recorded from two Marfona potato crops, with a total area of 4 ha located in Kermanshah–Iran (34°20′17.203″N, 46°19′56.807″E), taken with a moving platform with a speed of 0.13 m/s, under outdoor lighting conditions. Applying image processing, 3459 objects were extracted and used to train and test the classifiers. 126 color features and 60 texture features were extracted from each object. The main contribution of the proposed approach was the application of two metaheuristic algorithms to optimize the performance of a neural network classifier: first, the cultural algorithm is used to select the five most effective features, in order to improve computational efficiency; then, the harmony search algorithm is applied to find the optimal configuration of the network. This approach has been compared with a statistical method based on linear discriminant analysis. The experimental results show that the proposed expert system achieves an excellent identification accuracy of 98.38%, requiring less than 0.8 s of execution on an average PC.

1. Introduction

Agricultural engineering is one of the most promising fields for applying the latest advances in expert systems [1]. The purpose of these techniques is to reduce production costs, increase crop quality and productivity, and ensure the sustainability of the methods used. This is an essential aspect, since agriculture is one of the human activities that have the greatest impact on climate change. For example, the use of phytosanitary products, such as herbicides, insecticides and fertilizers, can have a significant global effect on the environment. Therefore, reducing the use of such products is a key objective in current agricultural expert systems.

In particular, weed control is a very active area of study in expert systems recently [2,3]. Weeds are considered to be harmful plants in agronomy, because of the competition against crops for getting water, minerals and other nutrients in the soil of the field. The techniques for weed control depend on the type of crop, the type of weeds and the planting method. Generally, the optimum time to control weeds begins with the planting of seedlings and continues until the crop growth concludes [4]. Nowadays, the most common way for removing weeds is spraying the herbicide uniformly all over the farmland, which means that areas without weeds are also sprayed. Therefore, new expert systems have been suggested in Precision Agriculture for weed control. These systems only spray in the exact spots where there are weeds and, so, reduce the risk of contamination of crops, humans, animals and water resources.

According to Wong et al. [5], spot spraying is the most effective way to reduce the use of different types of herbicides, and it will help to improve human health and prevent environmental pollution. They suggested a computer vision expert system based on spot spraying, considering different types of weed, which can be usually found in corn-growing lands. 80 images were taken from each type of weed; 60 samples were used for training a support vector machine classifier, while the remaining 20 images were used for testing. After capture, several shape, moment invariant and color features were extracted from each sample. Some of the

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https://doi.org/10.1016/j.compind.2018.03.001
0166-3615/

best features were selected by using a genetic algorithm, and then a classifier was applied using them. The experiments showed that the proposed classifier achieved an accuracy of 100% for all the classes. However, the results of this research could not be applicable for online spraying, for two reasons: (1) there was only one type of weed in the used images, but in general it is possible that several types of weeds and crops appear in an image; and (2) the images were taken in static mode, however in videos sequences, the camera is moving along the field and many frames may not be correctly focused, depending on depth of field and exposure.

Several researchers, such as [2,6,18,7,8], have studied the detection and classification of weeds and different types of crops based on color analysis. Aakif and Khan [9] believed that automatic classification of plants is the most important step to predict diseases, and to estimate their growth and health state. They studied 14 types of leaves of different species. 187 images were used in order to train the classifier. Features in the fields of morphology, shape and Fourier descriptors were extracted from each leaf. Then they applied artificial neural networks to classify these input vectors. Their results showed that the system was able to classify the 14 types of leaves with an accuracy of 68.3% by using morphology features, 77.8% using Fourier descriptors, 83.6% with shape features, and 96.5% applying a combination of all the features. In total, the accuracy of proposed system was acceptable for that database; however, it has to be considered that light intensity can change in outdoor lighting conditions, so the thresholds should change accordingly.

According to some authors [10,11], intelligent robots in agriculture should be able to recognize the information of their environment and their movement directions. But these two actions may be disrupted because of changing of light, temperature and humidity. Thus, they suggested that the robots focus on images taken from crop under different conditions, using different visual features. In this regard, Miao et al. [11] obtained 380 images with three types of light conditions corresponding to morning, noon and evening. Then, 8 features were extracted: the 3 components of color space HSL, the 2nd and 3rd components of HSV, and the 3 components of HSI. The feature vectors were classified using radial basis function neural networks. The results showed that this system was able to classify the image in sunny and cloudy days with an accuracy of 84.58% and 68.11%, respectively. This accuracy is not sufficient for a completely autonomous system, and would lead to many errors. Moreover, light intensity changes greatly during a day, so the use of just three light intensities does not seem to be enough for designing a general system under realistic conditions.

On the other hand, mechanical control and elimination of weeds in the traditional way present well-known problems such as destruction of crops. Thus, many researchers such as Meng et al. [12] have focused on integrating mechanical methods and expert systems. They suggested a computer vision system based on fuzzy logic for removing inter-row weeds. Their proposed system included a color video camera, an industrial laptop, a transverse displacement controller, a GPS receiver, a hydraulic system and blades to destroy weeds. The HSI color space was used for image processing, where the H component was thresholded to segment weeds. In this system, fuzzy logic was used for moving blades in longitudinal transverse directions. The proposed system was tested in 3 different speeds, 0.6, 1 and 1.4 m/s; the experiments showed that the highest transverse errors were 4.5, 5.5 and 6.8 cm, respectively. These errors can be considered acceptable, but if the image processing system is not trained for all lighting conditions, the errors would become greater.

Some authors have proposed the application of genetic algorithms in problems of weed detection. For example, Nguyen et al. [13] used genetic programming to distinguish rice and non-rice on 20×20 pixels windows. They observed that this approach greatly improved a simpler method based on color thresholding, achieving 90% accuracy. Watchareeruetai and Ohnishi [14] also

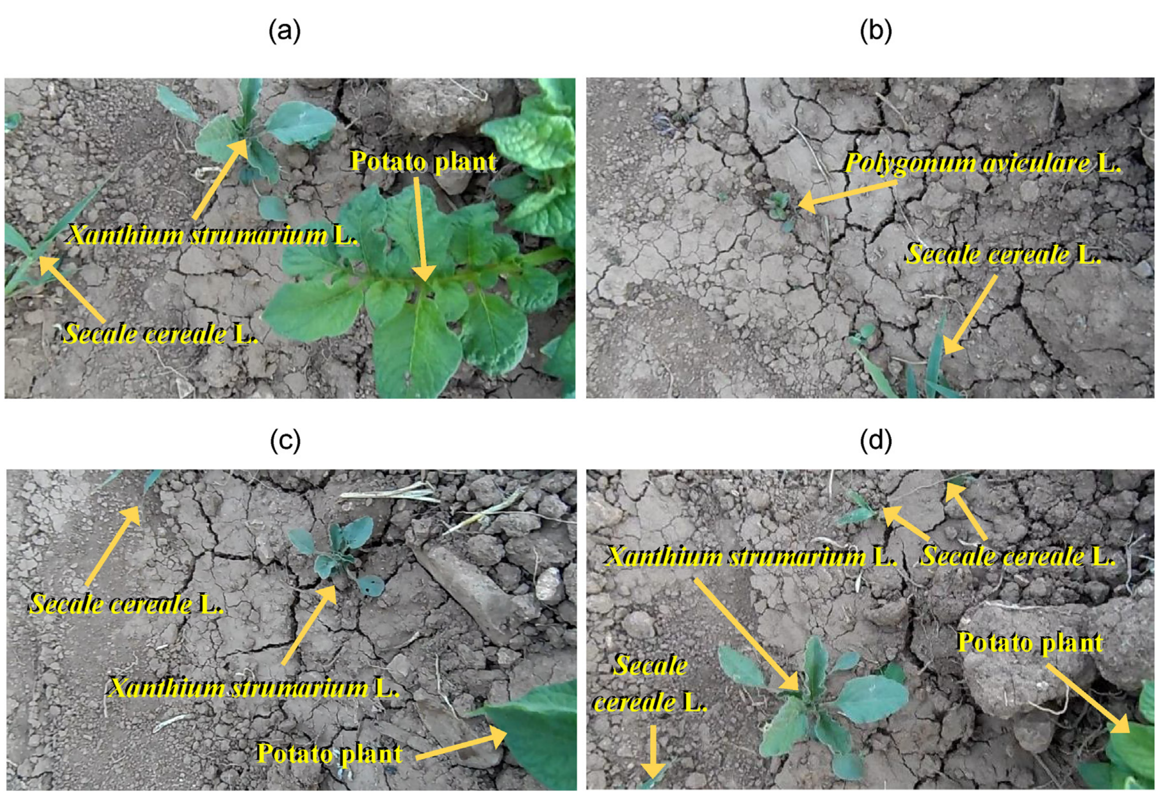

Fig. 1. Sample images used in the experiments, showing potato plants (var. Marfona) and the three types of weeds considered.