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Weed detecting robot in sugarcane fields using fuzzy real time classifier

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ABSTRACT

The objective of this research work is to propose a weed detecting robotic model for sugarcane fields that uses a fuzzy real time classifier on leaf textures. The differentiation between weed and crop and weed removal are the two challenging tasks for the farmers especially in the Indian sugarcane cultivation scenario. The automatic weed detection and removal becomes a vital task for improving the cost effectiveness and efficiency of the agricultural processes. The detection of weeds by the robotic model employs a Raspberry Pi based control system placed in a moving vehicle. An automated image classification system has been designed which extracts leaf textures and employs a fuzzy real-time classification technique. Morphological operators are applied to extract circular leaf patterns in different scales from the leaf images. An optimal set of features have been identified for the characterization of crops and weeds in sugarcane fields. A weed detecting robotic prototype is designed and developed using a Raspberry Pi micro controller and suitable input output subsystems such as cameras, small light sources and motors with power systems. The prototype's control incorporates the weed detection mechanism using a Raspbian operating system support and python programming. The designed robotic prototype correctly identifies the sugarcane crop among nine different weed species. The system detects weeds with 92.9% accuracy over a processing time of 0.02 s.

1. Introduction

Sugarcane is the second major cash crop in India (Murthy, 2010) besides cotton and it occupies about 3% of the total cropped area. Its share in value added agriculture is 6% and it contributes about 1.1% to the Indian GDP (Gross Domestic Product). The Indian production share alone amounts to more than 20% of the global share (Kshirsagar, 2008) and therefore it is an important source of income and employment for the Indian farming community. Sugarcane is considered as an energy crop, as it is used to produce, apart from sugar, other by-products such as renewable bio-electricity, bio-ethanol, bio-manure, alcohol, chemicals and fibre which improve ecological sustainability. More than five million farmers are either directly or indirectly involved in sugarcane cultivation in India (Solomon, 2014).

Sugarcane is a long duration crop which reaches its maturity in 11–12 months. Crop growth is very slow at the initial stage i.e. it takes 25–30 days to complete germination and another 90–95 days to complete tillering. Larger amount of nutrients and water is applied during the initial stages of growth as compared to the later stages. Sugarcane sets are planted continuously in rows with a spacing of 90 cm to 150 cm. The large amount of nutrients, moisture, solar radiation and wider spacing between crops also favor the growth of weeds in the sugarcane fields which prevent the crop from getting the nutrients.

Weed management is an essential practice in the sugarcane fields. Weeds compete with the crop for space, soil moisture, plant nutrients and solar radiation (Bakker, 2012). Especially in sugarcane fields, weeds reduce the germination and crop growth at the initial stage which in turn results in about 27% to 35% of yield loss. Hence, maintenance of the sugarcane field towards a weed-free condition becomes essential in the early growth phase (Rajenderkumar et al., 2014).

Weeds in these sugarcane fields are classified as grasses, sedges, broad leaved weeds and climbers wherein *Cynodon dactylon*, *Panicum* species, *Sorghum halopense*, *Chloris barbata*, *Dactyloctenium aegyptium* are family of grasses, *Cyperus iria* and *Cyperus rotundus* are family of sedges, Trianthema portulacastrum, Amaranthus viridis, *Portulaca oleraceae*, Commelina bengalensis, *Cleome viscosa* and *Chenapodium album* are broad leaved weeds and *Convolvulus arvensis*, *Ipomea sepiaria* and *Ipomea alba* are climbers (McMahon et al., 2000).

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Technological advances in computers and sensors have contributed to the use of automation in agriculture machinery, especially for weeding machines (Sujaritha et al., 2016). With automation, the weeding process is controlled electronically which reduces human intervention and optimizes the power provided by the machine.

There are several methods that can be used for weed control. Manual weed control is a method using bare hands or handheld tools to uproot weeds, while mechanical weed control involves the use of machines to perform weed control. Chemical weeding uses herbicides to control weeds, whereas biological weed control uses weed destroying organisms for weed control.

Modern agricultural practices introduce machine vision technologies in weeding. Machine vision is defined as the technique, method, or system of operating and controlling a process or mechanical device without human intervention. Machine vision technologies can be applied in two types of weed control methods: (i) Chemical weeding (ii) Mechanical weeding.

Typically, uniform application of herbicides is followed in the field which induces air, water and soil pollution. However, site specific application of herbicides would reduce the pollution and cost of weed control. Mechanical approaches use selective machines or add-on tools to uproot the weeds close to the crop, without damaging the crop (Weide et al., 2008).

Selection of the best weed management technique for sugarcane is governed by the factors such as geographic location, planting date, weed species present and method of irrigation. Since sugarcane is a long-season crop, a broad spectrum of weed control is required. Several herbicides are registered for selective weed control (Lamm et al., 2002; Zhang et al., 2012), but no single chemical will control all weeds that infest sugarcane fields. Frequently two or more herbicides may have to be combined sequentially or as tank mixes to achieve adequate broad-spectrum weed control. The weed species present will to a large degree determine the choice of herbicides in such combinations. Therefore, a mechanical weed control method which uses a rotavator blade and a robotic arm to uproot or remove the weeds from the field is used in the present system. This method increases tillering and sprouting, destroys insects (as they use the weeds as the initial breeding ground) and enhances aeration in the soil.

Machine vision (robotics) based mechanical weeding systems optimizes the power provided by the machine, and substitutes human input in a process with electronic hardware, sensors, actuators and software. Weed control, particularly within the crop row, is a process which requires the intelligence to distinguish between crop and weed which is usually done by manual labour. The disadvantage of this method is the unreliability of labour and the high cost incurred along with it. In order to obtain the advantages of both mechanical and manual approaches, the automation technology has been applied to weed management. An automated machine acquires the knowledge(machine learning) to identify and differentiate the crop plants from weed plants, and subsequently, removes the weed plants with an appropriate uprooting device(Bakker, 2009).

Colour, shape (Perez et al., 2000; Lamm et al., 2002), spectral (Zhang et al., 2012) and texture (Guijarro et al., 2011) are the predominant features used by the past literatures in this field. The following passages describe the existing methodologies used for weed identification in agricultural fields.

The shape features discriminate the broad and narrow leaves. Therefore Cho et al. (2002) assessed the shape features such as aspect ratio, elongatedness and perimeter to discriminate radish from weeds. In addition to roundness, seven invariant central moments (ICM) have also been included to identify corn and soybean from weed species (Woebbecke et al., 1995). However, shape features require the individual leaves to be isolated without overlap which is impossible in the sugarcane field scenario. Therefore shape features are not involved in the proposed feature set.

Before 1998, low level texture features such as skewness, mean, variance (Franz et al., 1991) gray level co-occurrence matrix, angular second moment, inertia, entropy, local homogeneity are evaluated in soybean, maize and corn fields (Meyer et al., 1998). Later, Gabor wavelet texture feature occupies the feature set with tremendous improvement in weed/crop classification process (Tang et al., 1999).Texture features along with one of the modern classifiers such as Fuzzy Clustering, Bayesian Classifier, Support Vector Machine, and neuro-fuzzy classifiers (Tang et al., 2003; Cruz et al., 2013;Rainville et al., 2014; Zafar et al., 2015) have been employed in crop recognition systems.

The above said methodologies have been employed in the commercial automated weed killing implements such as Photonic Detection Systems Pty Ltd (formerly Weed Control Australia), Weedseeker (formerly Patchen), and Rees Equipment. These commercial systems are used for broad leaved crops such as maize, corn and soybean where there is a stark difference in shape between the crops and weeds which is easily distinguishable. But the above systems might not be used for sugarcane, as the sugarcane crop bears a high level of similarity in shape and size with the weeds during the initial stages of growth.

Recently, the National Centre for Engineering in Agriculture (NCEA) has developed a weed spot sprayer which differentiates between Guinea Grass and sugar cane (Mccarthy et al., 2012). The structure detection algorithm that identifies the size, prominence, regularity and 'blobness' of the structure (developed by Frangi et al. (1998)) has been implemented in the above system. The values of the parameters have been empirically determined through iterative analysis on field images. This kind of empirical analysis might not fit all the environmental and soil conditions. Therefore, an algorithm which is suitable for Indian soil ecological conditions is necessary and it is to be verified pragmatically.

The weed detection system presented in this paper has four major steps. They are: (i) colour based greenness identification (ii) texture extraction (iii) feature vector generation and (iv) classification. The contribution of this paper lies in the texture extraction phase, where the morphological operations are used to extract the distinguishing characteristics between the weed and sugarcane leaves. The system also considers the surface texture of the leaf parts (venation) rather than the size and shape of the individual leaf and it is particularly robust due to its rotation invariance property. Also, the segmentation in agricultural field images is different from the segmentation in medical or any other scientific images because, in agricultural images, the part which is suitable for segmentation can be identified and that part alone can be used for classification. This reduces the computational load as not all the components of the image are segmented. Unlike past literatures, this flexibility in segmentation is utilized in the proposed system.

2. Materials and methods

The Architecture of this weeding system is given in Fig. 1. The three major components of the system include: (i) Image acquisition system, (ii) Processing system and (iii) Control system. These subsystems are explained in the following subsections.

2.1. Image acquisition system

In sugarcane fields, the sugarcane chip bud seedlings are planted in rows with inter-row distance of 150 cm and intra row distance of 60 cm. Two different cameras are employed for capturing inter - row and intra row images. An intex IT-105 web camera with 3264×2448 image capture resolution (Cam1) and a simple