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# A real-time plant discrimination system utilising discrete reflectance spectroscopy

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ABSTRACT

An advanced, proof-of-concept real-time plant discrimination system is presented that employs two visible (red) laser diodes (635 nm, 685 nm) and one near-infrared (NIR) laser diode (785 nm). The lasers sequentially illuminate the target ground area and a linear sensor array measures the intensities of the reflected laser beams. The spectral reflectance measurements are then processed by an embedded microcontroller running a discrimination algorithm based on dual Normalised Difference Vegetation Indices (NDVI). Pre-determined plant spectral signatures are used to define unique regions-of-classification for use by the discrimination algorithm. Measured aggregated NDVI values that fall within a region-of-classification (RoC) representing an unwanted plant generate a spray control signal that activates an external spray module, thus allowing for a targeted spraying operation. Dynamic outdoor evaluation of the advanced, proof-of-concept real-time plant discrimination system, using three different plant species and control data determined under static laboratory conditions, shows that the system can perform green-from-green plant detection and accomplish practical discrimination for a vehicle speed of 3 km/h.

## 1. Introduction

To maximise crop yield, blanket spraying of herbicides and insecticides is commonly used for weed and pest management. The application of such chemicals is often done terrestrially using an appropriately configured tractor or aerially, using a crop duster. A cost effective system for weed control, using spot-spraying of herbicides at appropriate periods during the cultivation cycle, is of interest to farmers due to the associated benefits of managed costs, reduced herbicide application and crop yield optimisation.

In recent years, the collective application of new technological advancements and improved management practices to farming has given rise to the field of Precision Agriculture (PA) (Zhang et al., 2002), of which a major aspect is Site-Specific Crop Management (SSCM) for optimised, efficient field-crop production. The management of weeds through an agricultural crop's growth cycle, is one such area that has attracted considerable research interest. Reviews by Zwiggelaar (1998) and Noble et al. (2002) have concluded that weed/soil (green-from-brown) and crop/weed (green-from-green) discrimination, utilising spectral reflectance and hyperspectral/multispectral imaging techniques, has achieved varying levels of success. In particular, spectral analysis has been used as a method for discriminating plants from soil (green-from-brown discrimination) (Felton and McCloy, 1992; Brownhill, 2006). Fundamental work presented by Wang et al. (2001) quantifies plant spectral characteristics by using five feature wavelengths and four normalised colour indices for crop/weed (green-from-green) discrimination. The work led to the development of an optical weed sensor capable of detecting wheat from specific weeds under controlled laboratory conditions. More recently, Deng et al. (2014) have investigated the application of Support Vector Machine (SVM), Artificial Neural Network (ANN) and Decision Tree (DT) based classifiers to compare the classification rates for plant spectral measurements taken in the 350–760 nm visible wavelength range and the 350–2500 nm visible and NIR wavelength range. Experimentally, spectral irradiance measurements for the test crop (corn) and weeds (*Dchinochloa crasgalli* and *Echinochloa crusgalli*) were performed in the field, using a handheld spectroradiometer, with results showing that the visible light range proved adequate to meet discrimination requirements for the given test plants. An innovative approach presented by Sahba et al. (2006) and Paap et al. (2008) demonstrated generalised green-from-green discrimination using a novel optical architecture, with the eventual objective of practical application of the technology to weed treatment, using spot spraying in

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field-crop production. The application of hyperspectral measurement techniques to the problem of crop/weed discrimination has also been reported on in the literature. Shapira et al. (2010) have investigated using ground based hyperspectral imaging to detect grasses and broadleaf weeds among cereal and broadleaf crops. The proximity based hyperspectral camera yielded hyperspectral resolution with high spatial resolution, enabling considerable spectral and spatial separation between crop and weed. In a different approach, Eddy et al. (2013) have investigated the feasibility of using reduced hyperspectral bandsets and ANN classification for discriminating between crop-field pea (*Pisum sativum*), spring wheat (*Triticum aestivum*), canola (*Brassica napus*) and weed-wild oat (*Avena fatua*), redroot pigweed (*Amaranthus retroflexus*). Reduced sets of narrow wave bands were created using Principal Component Analysis and Stepwise Discriminant Analysis with experimental results showing that plant discrimination using an ANN classifier was feasible and could provide considerable computational savings due to the reduced data dimensionality. The drawback however, was the high overhead required to train the classifier for successful operation.

This paper reports on recent results obtained from research into the development of an advanced proof-of-concept real-time plant discrimination system based on discrete spectral reflectance measurements for green-from-green plant discrimination. The developed system is tested for the discrimination of Anthurium (*Anthurium andraeanum*) from Sunkisses (*Ipomoea batatas* var. sunkisses) and Dandelion (*Taraxacum officinale*).

Experimental results show that practical green-from-green discrimination at a farming vehicle speed of 3 km/h can be achieved. At higher speeds, due to identified hardware limitations, the discrimination capability and accuracy declines.

## 2. System overview

The real-time Plant Discrimination Unit (PDU) is comprised of two 3-wavelength laser modules, two coated optical cavities, a high-speed linear photodetector array in the form of a line scan camera and an electronic circuit board housing six sub-modules, Fig. 1. These are a laser driver, analogue and digital power supply units, a temperature controller, a central processing unit, a spray nozzle activator and a line scan camera driver. The PDU is robustly packaged, using a rigid base plate and an accompanying light weight dust cover, to overcome harsh operation conditions such as shocks, vibrations and high temperatures.

The optoelectronic architecture of the PDU, as presented, has the following benefits:

1. The collimated, split laser beams enable spectral reflectance measurements to be taken from a small area of leaf of the target plant.
2. The laser module beam combiner/optical cavity design enables the laser beams to illuminate the same spot on the leaf, for all wavelengths, making the measured spectral reflectance spatially accurate with regards to different leaf morphologies.
3. The high dynamic range of the line scan sensor, when compared with area scan sensors of the type used in multi-spectral imaging, gives a better precision and a higher accuracy of the measured spectral properties.
4. The low complexity of the discrimination algorithm means that it is not computationally intensive, therefore providing true real-time performance.

### 2.1. Vegetation illumination

Fig. 2 shows the layout of the plant discrimination unit and illustrates how laser beams are generated to illuminate the vegetation.

#### 2.1.1. Beam generation

Each laser module uses three 4 mm collimated laser sources, two red (635 nm and 685 nm) lasers and one near-infrared (785 nm), with output power levels of 30 mW, 50 mW and 50 mW, respectively. Within a module, each laser is independently mounted onto an alignment stage using alignment screws, so that all laser beams are aligned along the same optical axis. Two fixed,

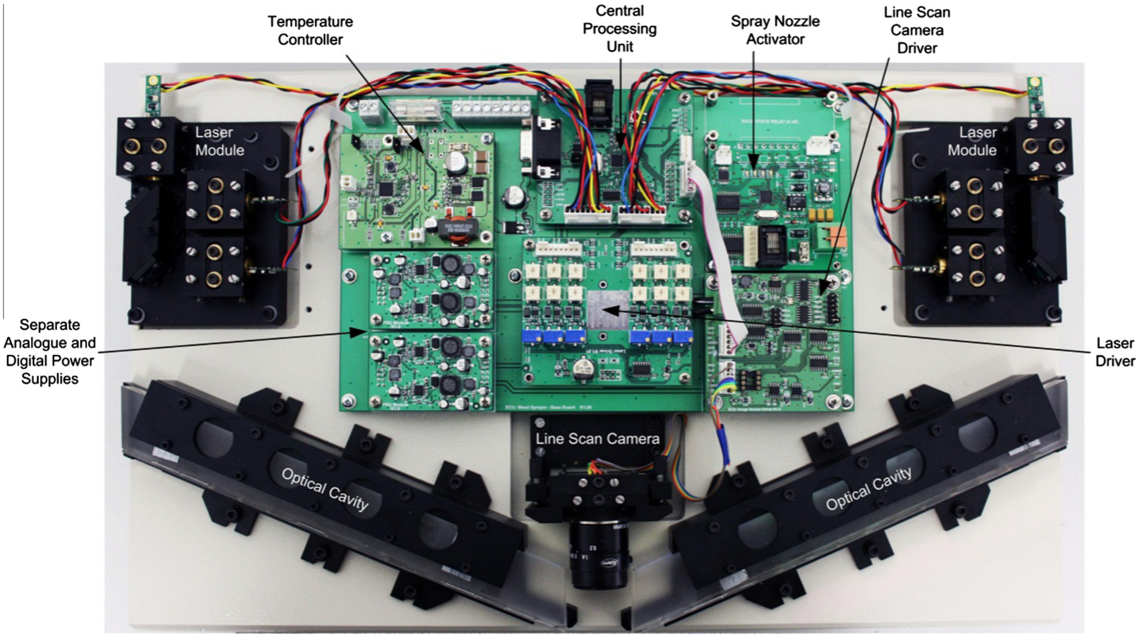

**Fig. 1.** Photograph of the developed real-time plant discrimination unit (PDU). It comprises two 3-laser modules with alignment and locking mechanisms, two optical cavities, a high-speed linear photodetector array in the form of a line scan camera and an electronic motherboard housing six daughter-boards, namely a laser driver, analogue and digital power supply units, a temperature controller, a central processing unit, a spray nozzle activator and a line scan camera driver.