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Evaluation Of An Optical Image Sensor For Use In The Microphotonic Real-Time Vegetation Discrimination System

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Abstract – A comparison between the performance of a commercially available line scan camera and a linear sensor array employed in a micro-photonic real-time vegetation discrimination system for use in selective herbicide spraying systems is presented.

Introduction

To maximize productivity and profitability in agriculture industries, the detection and eradication of weeds in crop fields is crucial [1]. Farmers currently either spot-spray weeds by hand or blanket-spray entire crop fields. Blanket spraying wastes herbicide, reduces crop yields and increases chemical loads on ecosystems. An automatic real time weed detection system, where detection and treatment are performed at the same time, can yield considerable reduction in the amount of herbicide used.

The prototype plant discrimination system described in [2 and 3] uses an expensive image sensor (line scan camera) to detect the intensity of reflected light from a plant sample. In this paper, the performance of an alternative cost-effective image sensor (linear sensor array) is evaluated and compared with the line scan camera. The experimental results presented show a comparison of the recorded intensity of reflected light from a reference sample over time and the calculated spectral characteristics for four plants using both image sensors.

System description

The vegetation discrimination system is comprised of a laser combination module, a multi-spot beam generator and a linear image sensor. Fig. 1 shows a schematic representation of the vegetation illumination system where a leaf, stem or soil spot is sequentially illuminated by laser beams of different wavelengths. Discrimination is achieved by recording and processing plant reflectance data for each wavelength.

Laser combination module

The laser combination module contains three laser diodes of different wavelengths appropriately aligned with two free-space beam combiners. The laser module produces three collimated and overlapping laser beams with the same polarization angle. These collimated beams are launched into an optical substrate which generates a collimated line array of up to 15 output

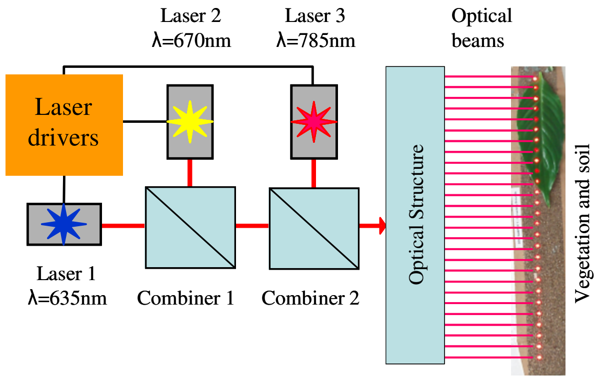

Fig. 1. Vegetation illumination system: a laser combination module with three laser diodes and an optical structure projecting multiple laser beams onto vegetation and soil.

beams of diameter 4 mm, spaced at 12mm. An advantage of using multi-spot beam generation for vegetation illumination is the stable alignment of the generated beams regardless of the movement of the whole sensor housing mounted on a moving farming vehicle.

Image Sensors

The intensity of the reflected light from a sample illuminated by the multi-spot beam generator is recorded by an image sensor placed behind an appropriate C-mount lens assembly. Two optical sensors were independently evaluated: a line scan camera [2,3] and an alternative linear sensor array. The line scan camera has 1024 pixels of size 14 × 14µm, 12 bit resolution and line rate of up to 68kHz. The linear sensor array has 102 pixels of size 77 × 85µm, 8 bit resolution and line rate of 10kHz. The image sensor with larger pixel size is less sensitive to misalignment with the multi-spot beam generator. The line rate of the linear sensor array is sufficient for detection when the plant discrimination system is mounted on a farming vehicle traveling at a typical speed of 20km/h.

Discrimination method

The plant discrimination method is based on determining the slope in the reflectance at the three wavelengths used. The two slope values, S_1 and S_2, are defined as:

$$S_1 = \frac{R_{635} - R_{670}}{\lambda_{670} - \lambda_{635}} \quad \text{and} \quad S_2 = \frac{R_{785} - R_{670}}{\lambda_{785} - \lambda_{635}}, \qquad (1)$$

where λ_n is the wavelength of the laser diode in nanometers, $R_\lambda = I_\lambda / P_\lambda$ is the calculated reflectance, I_λ is the peak recorded intensity in digital numbers and P_λ is the measured optical power for each spot generated by the optical structure.

Results and discussion

The stability over time of the current image sensor (line scan camera) used in the prototype weed discrimination system and an alternative linear sensor array have been investigated (Fig. 2). The effect of image sensor stability on discrimination capability of the system has been examined with four different plants.

Fig. 2 shows the variation in the digital response of the two optical image sensors over time to one spot on a reference sample. This spot was sequentially illuminated by 635nm, 670nm and 785 nm laser beams at ten second intervals over a period of 10 minutes. The line scan camera readings (thin lines) showed significant fluctuation for all three wavelengths in comparison with the linear sensor array.

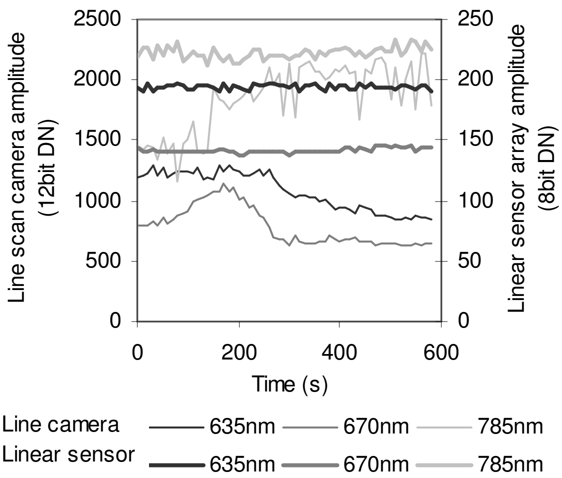

Fig. 2. Response in digital numbers (DN) of two optical image sensors over time to one spot on a reference sample sequentially illuminated by 635nm, 670nm and 785 nm laser beams.

The effect of the variation over time in the response from the two image sensors on the capability of the weed discrimination system was evaluated by calculating values of spectral slopes for four different plants: Spathiphyllum, Anthurium, Acacia saligna and Eucalyptus marginata. Fig. 3 shows the average values and standard deviations for 20 measurements of S_1 and S_2 (Eq. 1) from a single laser beam illuminating one spot on a leaf of each plant.

The standard deviations of S_1 and S_2 calculated with the line scan camera are significantly larger than the standard deviations for the linear sensor array. There is little overlap between the slopes S_1 and S_2 of plants using the linear sensor array making it more applicable

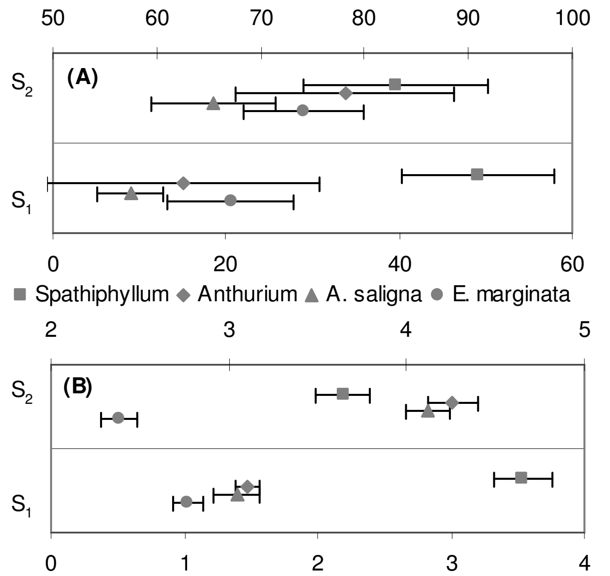

Fig. 3. Average slopes S_1 and S_2 ± standard deviation (arbitrary units) for four sample plants determined by (A) line scan camera and (B) linear sensor array.

than the line scan camera in the vegetation discrimination system.

Conclusions

The stability over time of a line scan camera and a linear sensor array has been independently evaluated to compare their suitability as an image sensor in a micro-photonic vegetation discrimination system. The cost-effective linear sensor array has shown superior stability over time compared with the line scan camera and exhibited a lower standard deviation of calculated spectral characteristics of sample plants and consequently significant improvement in vegetation discrimination. Future development will integrate the linear sensor array with an embedded control system which will operate the vegetation discrimination system.

Acknowledgements

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