ID76 Weed detection based on spectral imaging systems with CMOS-cameras

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Abstract

At presence sensor systems for automated real-time detection (and later on treatment) of weed are not available in products. So far different sensor techniques are still in an experimental stage. In order to improve and speed up the process of transferring scientific results into prototypes, reliable online measurements of the total weed population have come into focus. In order to fulfill conflicting specifications with respect to high selectivity and high-speed as well, a spectral imaging system has been developed thereby measuring plants in the mm-range at velocities up to 10 km/h.

Advantage has been taken from a commercially available optical system, which scans one line thereby splitting each detection point in to a spectral pattern. The authors have combined the optics with new CMOS imaging technology and the development of specific electronic components. Moreover, a software for the configuration and control has been implemented. The spectral imaging system has been successfully implemented in a test module for first field tests. A trigger signal for an actuator is available and thus allows the local application of chemical weed control.

Keywords: weed detection, image processing, CMOS cameras, spectral imaging

Introduction

Requirements of environmental protection are given increasingly attention in agricultural applications. In particular, unselective weed control by spraying a homogeneous pattern of herbicides all over the field has to be replaced by more sophisticated methods, both from an environmental and economical point of view. The key component for introducing local weed control in the field of precision farming is a detector for online crop/weed-distinction. The local application of a sprayer, a mechanical hoe or other actuators strongly depends on a reliable sensor system suitable for field applications. At the moment, however, no commercially available system for weed detection is available.

On the other hand, in the past years significant progress has been achieved in several research and development projects for online sensor systems using spectral, geometric or other signatures of plants, soil and environmental conditions. So far developments with photodiodes (Wartenberg, 2000), CCD-cameras (Sökefeld, 2002) or multi-sensor systems (Ruckelshausen, 1999) have been improved, however, prototypes or products in the market are still not available. The most important – still unsolved – problem is the detection of green weed in green crop under field conditions.

In order to improve and speed up the process of transferring research results into the market, reliable online measurements of the percentage of the total weed population – excluding crop detection – have come into focus. If such a system – as a first step of sensor-based weed control – could demonstrate it's ecological and economical advantages in commercially available systems, the transfer of further developments to products would be strongly supported.

In order to fulfill the specifications of a corresponding detection system with respect to high selectivity and high-speed as well, the following concept has been chosen: While the system design – including the development of electronic components and software – has been realized by the authors, as much as possible commercially available devices have been selected, especially an optics for spectral imaging ("ImSpector") and CMOS cameras.

Materials and Methods

Spectral Imaging for Weed Detection

A well-known method for plant/soil distinction is the measurement of spectral differences for the reflection of light. Measurements of the integral light intensity reflected by an area on a field, however, always involve a mixture of soil and plants thereby resulting in problems for the interpretation of measurement results. On the other hand, with a standard miniature spectrometer precise informations can be achieved, but only a point (or a very small area) can be analyzed.

In order to measure a significant area with a high selective spectral sensitivity, the authors have recently applied a commercially available optical system – "ImSpector" (Borregaard, 1997) - for weed detection, which scans one line thereby splitting each detection point into a spectral pattern (Ruckelshausen, 2000). Thus a spectral analysis can be performed for each point if the corresponding position/wavelength matrix is detected and analyzed. The working principle is summarized in figure 1.

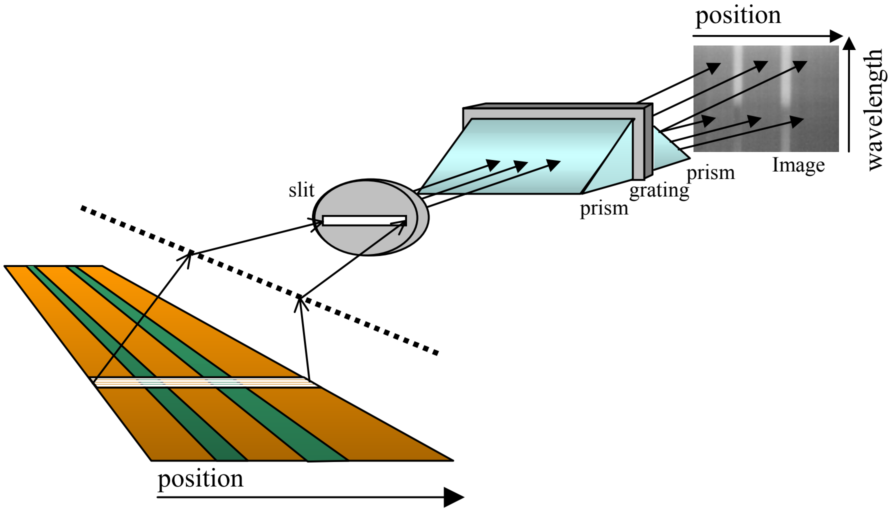

Figure 1. Basic working principle of the ImSpector (Ruckelshausen, 2000). The spectral information for each point of a narrow stripe is available in the position/wavelength matrix.

The application of this "spectral scanner" for weed control is not limited to the distinction of plant and soil as described here. Since the pointwise reflection signal can be used as a signature for crop/weed detection in several cases (see for example: Ruckelshausen, 2000), future options of the systems are possible.

Architecture of the Imaging System

New digital CMOS imaging devices have now been applied for the detection of the two-dimensional information – position versus wavelength. Digital CMOS sensors allow the addressing and fast image processing of single pixel informations, thereby resulting in higher flexibility and speed as compared to standard CCD cameras where a whole frame has to be read out prior to image processing. Moreover the choice of linear or logarithmic response as well as automatic gain control are important figures with respect to variations of the light intensitiy.

In order to correlate the spectral informations with the local position on the field a position signal is included. This allows the generation of a trigger signal for an actuator for weed regulation. The architecture of the system is shown in figure 2.

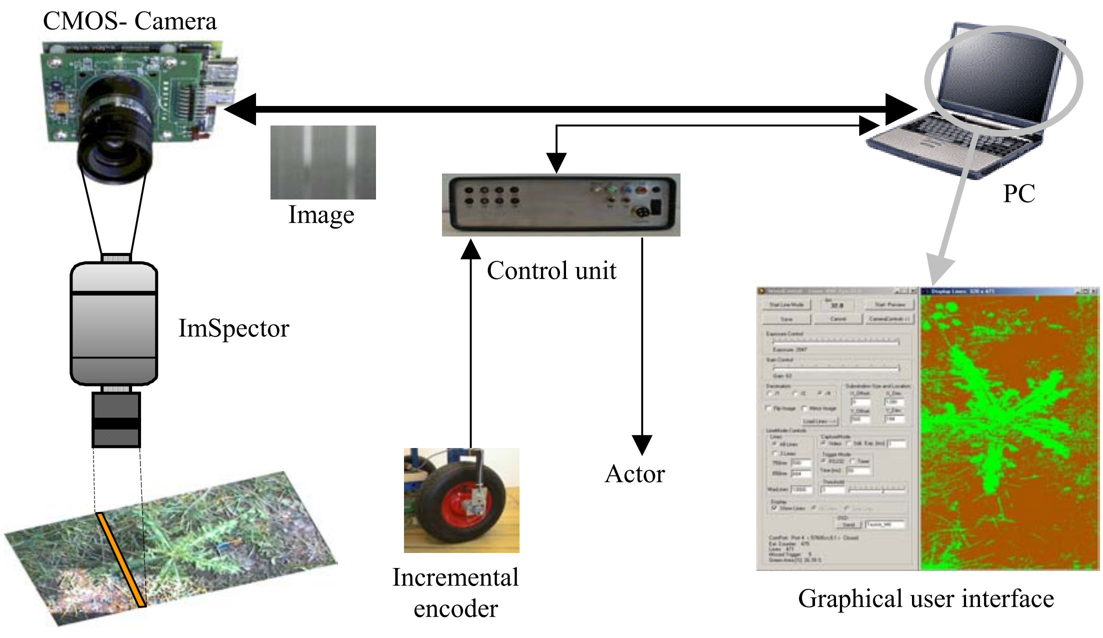

Figure 2. Architecture of the Spectral Imaging System including the optics (ImSpector), CMOS-camera, position information, and signal processing.

Two different CMOS cameras (see table 1) have been evaluated in combination with the ImSpector: (A) A commercially available PC-based camera system using a linear CMOS imager (PixeLINK); (B) A microcontroller-based development using the FUGA-1000 CMOS-sensor with logarithmic response. For system B no PC is necessary.

Table 1: Characteristic Parameters of the Applied CMOS Imagers

	PL-A633 (PixeLINK)	Fuga 1000 (Fillfactory)
Resolution (Maximum)	1280 x 1024	1024 x 1024
Response	Linear	Logarithmic
Data rate	24 M pixels/sec@8bit	10 M pixels/sec@8bit
Adressability	Line	Pixel
Dynamic	66 dB	120 dB

Software "*WeedControl*"

The software *WeedControl* has been developed in order to perform the data communication with the camera including the camera settings, the image processing, the inclusion of the position information and the resulting generation of a trigger signal for an actuator. For experimental purposes parameters can be changed or data and graphics can be generated or displayed as defined in the graphical user interface.

Results and Discussion

The measurement setup and a standard illumination (halogen lamp) are mounted to a vehicle for field tests (see figure 3). An additional video camera system has been implemented for experimental purposes, where the video image as well as additional measurement signals (example: position sensor) can be correlated to the measurement results. This electronic system is helpful for analyzing all informations at a given position.

Figure 3: Mobile unit for measurements in the field and greenhouse.

The maximum velocity depends on the sampling rate (distance between two measurement points) and the number of selected pixels of the CMOS camera. Typical data are summarized in table 2, thereby taking into account the data acquisition, data analysis and the trigger signal generation.

Table 2: Maximum velocities including all system aspects as a function of the number of selected pixels and the sampling rate.

Number of Pixels	Distance between 2 measurements		
	1 mm	3 mm	5 mm
1024	0,36 km/h	1,08 km/h	1,80 km/h
256	1,44 km/h	4,32 km/h	7,20 km/h
128	2,70 km/h	8,10 km/h	13,5 km/h

The measurements are performed between the rows or in a tram line with a selected width of about 14 cm at a height of 40 cm. Figure 4 shows measurement results. The total weed population is calculated and a certain threshold can be selected as a trigger signal for an actuator.

Figure 4: Measurement results for plant-soil distinction by setting corresponding trigger levels: camera signal (top), visualized output of the processed ImSpector signal (middle), weed population in percent (bottom).

Plants even smaller than 1 mm have been detected at lower velocities, typically the minimum dimensions are about 1 to 2 mm. In first field tests both sensor versions have been successfully applied up to 12 km/h. Furthermore tractor-mounted experiments of the system for various field conditions and the application of a sprayer are carried out.

Conclusions

A spectral imaging system for online measurements of the total weed population has been developed and successfully applied in first field experiments. The system combines high sensitivity, relatively large measurement width and high-speed application whereas for other solutions these conflicting parameters require compromises. The first promising results have to be confirmed by additional measurements and the application of the sprayer. Moreover, the system might be applied for crop/weed distinction in the future.

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