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Interchanging detectors and actuators for intra-row weed control

An electronic interface description

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Preface

This research on innovative (non-chemical) weed control was done for the Dutch ministry of agriculture, nature and food quality. It is a part of the research cluster 'preservation of production and transition' (BO-07). This cluster distinguishes a double goal, aimed at preserving production and a 3-p (people, planet, profit) broad and long term oriented transition to sustainable agricultural systems. Research on innovative systems, described in this report, contributes to these goals.

Abstract

Throughout the years a number of machines have been developed (or are in a developmental stage) for intra-row weed control. These machines are able to detect crop plants within crop rows and control an actuator that controls the weeds between them. Almost all machines have a separate detection unit and a separate actuation unit. In intra-row weed-control factors like crop type, growth stage, weed infestation and soil moisture content play an important role in selecting the best detector and actuator for a particular field situation. Detectors and actuators should be interchangeable to be able to freely configure a machine to accomplish an optimal setup for given field conditions. To achieve this interchange ability an electronic interface definition between detection units and actuators is presented in this document. The proposed interface definition, with only two components (detector-actuator distance and signal level definition), is relatively simple and can be used with almost all existing and new detection units and actuators. Thanks to its simplicity, it can also be used on multiple-row detection units. The interface enables farmers to achieve an optimal machine-setup, without worrying about electronic incompatibility issues.

1. Introduction

Weed control in between crop rows can be done efficiently with currently available techniques. Weed control in the crop rows ('intra-row weed control') is still a problem, especially in organic farming. Throughout the years many (mechanical) techniques have been developed to control weed plants in the crop row. Examples of these techniques are finger- and torsion weeders (PPO, 2006). Unfortunately the effect is often sub-optimal because these weeders are non-selective (the weeding tool itself is unable to distinguish between crop- and weed plants). The efficacy of the operation often depends on factors like plant height and rooting depth. In general, if there is enough difference between crop- and weed plants (large plants and small weeds), non-selective weed control can perform well in many cases. Nevertheless the aggressiveness of the operation needs to be considered: the more aggressive, the more weeds will be controlled but often at the risk of damaging the crop plants.

Selective mechanical weed control (a distinction is made between weed- and crop plants) could offer a solution. By explicitly differentiating between crop and weed plants the weeds can be controlled aggressively whilst the crop plants can be left untouched.

A number of machines have been developed that can perform such selective intra-row weed control (Achten & Molema, 2005; Achten & Molema, 2006; Poulsen, 2006). These machines are able to detect crop plants within crop rows and are able to control an actuator that removes the weeds between them. Almost all machines consist of a detection unit and an actuation unit.

The detection unit (detector) is responsible for sensing the crop row and detecting crop and/or weed plants. Crop rows can be sensed with various sensor types: interruptible light beams (Achten & Molema, 2005; Achten & Molema, 2006), cameras (Poulsen, 2006) or, possibly, mechanical sensors. Sensor signals are processed (e.g. by using microprocessors) to determine if actuation is needed or not.

The actuation unit (actuator) is responsible for weed control. It is controlled by the detection unit and it can be a moveable hoe, a flame, a sprayer nozzle, a water jet cutter and so on.

Factors like crop type, growth stage, weed infestation rate and soil moisture content play an important role in selecting the best detector and actuator for a particular field situation. Machines for intra-row weed control often have a rigid setup. This means that detection units and/or actuation units are non-interchangeable. This limits the machine's usability. To increase the machine's usability, detectors and actuators should be interchangeable, even between different brands of machines. In this way a machine for intra-row weed control can be freely configured to accomplish an optimal setup for given field conditions.

To achieve this interchange ability a well described interface between detectors and actuators is needed. This document describes such an interface. In chapter 2 this interface definitions are defined. Chapter 3 gives some examples on practical implementation of the interface, also for use with existing detectors and actuators. This chapter is followed by a discussion and conclusions.

2. Interface definition

To achieve interchange ability between detectors and actuators a well described interface between detectors and actuators is needed. The interface described in this chapter consists of two components: 1) a mechanical definition and 2) an electronic definition.

2.1 Mechanical definition

A typical machine for intra-row weed control has a detection unit and an actuation unit. In the direction of travel, the detection unit is always in front of the actuation unit. A typical machine for intra-row weed control is presented schematically in Figure 1.

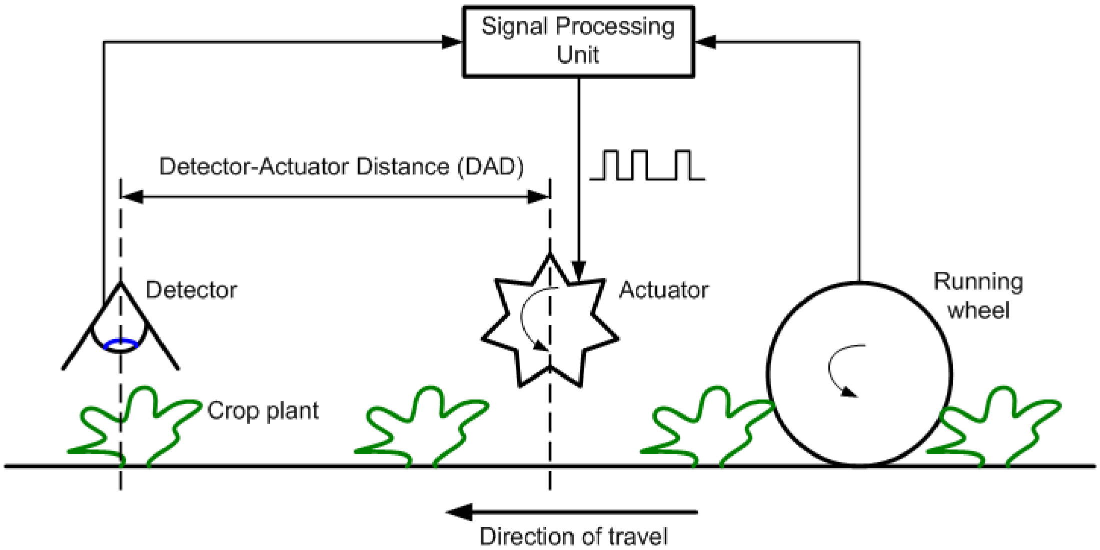

Figure 1. Schematic lay-out of a machine for intra-row weed control defining the Detector-Actuator Distance (DAD).

The detection unit detects crop and/or weed plants and controls the actuator in a way that weed plants are removed and crop plants remain undamaged. In this case perfect detection and an 'ideal actuator' (no delays, immediate actuation) are assumed.

The detector will determine if the actuator should be engaged or not. This command can be seen as a binary signal because it has two states: 'actuation' and 'no actuation'. An exact timing of this actuation signal is very important to avoid crop damage. Because the detection unit is positioned in front of the actuation unit, the detector needs to delay the actuation signal until the actuator is at the spot where detection took place. Therefore the travelled distance should be measured. In most cases a Local Positioning System (LPS) is used; positions are measured in a local reference frame. For this purpose, a running wheel can be used to measure the travelled distance in a local reference frame.

The distance between the detector and an ideal actuator is called 'Detector-Actuator Distance' (DAD). If a crop is detected at distance d, the actuator should be disengaged at distance d+DAD to avoid damage to the crop. The ideal actuation unit can then be interchanged with any other ideal actuation unit, as long as the DAD is maintained. The same goes for interchanging detection units.

The DAD is therefore an important value for interchange ability of detection- and actuation units. The DAD may be a fixed (factory-defined) value or even a variable (user-defined) value, it may be visible on the cover of the detection unit or on a electronic display, as long as its value is known.

2.2 Signal definition

As stated previously, the signal that 'tells' the actuator to engage or disengage is a binary signal. To be able to interchange detection and actuation units this signal needs to be standardised. A well-known and commonly used method for interfacing digitally controlled devices is TTL (Transistor-Transistor Logic). TTL gates operate on a nominal power supply voltage of 5 volts (V). Ideally, a TTL 'high' ('1') signal would be 5.00 V exactly and a TTL 'low' ('0') signal 0.00 V exactly. However, real TTL gate circuits cannot output such perfect voltage levels, and are designed to accept 'high' and 'low' signals deviating substantially from these ideal values. 'Acceptable' (voltage levels guaranteed by the gate manufacturer over a specified range of load conditions) input signal voltages range from 0 V to 0.8 V for a 'low' logic state, and 2 V to 5 V for a 'high' logic state. 'Acceptable' output signal voltages range from 0 V to 0.5 V for a 'low' logic state, and 2.7 V to 5 V for a 'high' logic state (Figure 2).

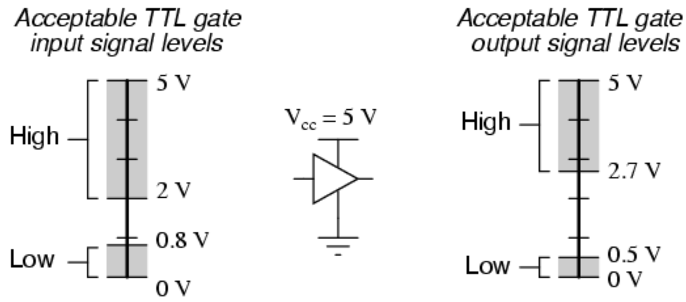

Figure 2. Transistor-Transistor Logic signal levels for input and output signals.

The digital actuation signal that is send by the detection unit should comply with the TTL-specifications. In this context, the binary signal has two states: '0' means 'no actuation' and '1' means 'actuation'. This means that the signal level for 'no actuation' should be between 0 and 0.5 V and signal level for 'actuation' should be between 2.7 and 5 V. The detection unit should be capable of sourcing 20 mA. An actuator should not drain more than 20 mA to avoid damage to the detection unit. Amplification circuitry in the actuator may be necessary.

2.3 In short

The interface between detection unit and actuator is a signal that complies to the TTL standard. A logical 'high' means 'actuation' and a logical 'low' means 'no actuation'. The distance between detection point and actuation point, the so-called Detector-Actuator Distance or DAD, should be provided by the manufacturer of the detection unit.

3. Practical implementation

The interface definition in chapter 2 is based on ideal detectors and actuators. Such devices do not exist. In order to apply the interface definition on ‘real-world’ detection units and actuators some practical implementation suggestions are given in this chapter.

3.1 Determining Detector-Actuator Distance

In many cases the Detector-Actuator Distance (DAD) is an unknown variable (e.g. in case of existing detection units or detection unit-actuator combinations). In order to use the detection unit with any actuator the DAD needs to be determined. This can be done in several ways. A simple method is to attach a LED (Light Emitting Diode) to the output of the detection unit, run the detection unit over a uniform, weed free (dummy) crop with a regular planting distance. It is assumed that the LED is off when a plant is detected in front of it. Whilst the crop plants pass the detection unit, the LED will turn on and off. The travelled distance between several transitions of the LED (going from ‘on’ to ‘off’ or vice versa) should be averaged to determine the DAD.

3.2 Non-ideal and smart actuators

The interface definition in the previous chapter assumed perfect actuation (no delays, immediate response to the actuation signal). In practice, there is some delay between the reception of the signal and the actual actuation. The delay is often caused by mechanical limitations (inertia) of the actuator. There are several ways to take this delayed response into account.

The first way is to enlarge the distance between detection unit and actuator. Due to this increased distance the actuation signal will be brought forward. How much the distance between detector and actuator needs to be increased depends on the characteristics of the actuator. If the actuator’s response time is constant the increase in distance is speed dependent; the higher the speed, the larger the increase in distance is needed.

The second way to cope with actuator delays is to add intelligence to the actuator. This means that the actuator has a fixed distance to the detector and determines when to engage and when not by itself. The decision when to engage or disengage can be made by a (micro)computer on the actuator. Based on sensor information and actuator characteristics the actuator can be controlled intelligently. For example, an actuator with a fixed response time can be controlled depending on the measured forward speed. The forward speed could be measured using the same odometer as is used for the detection unit (e.g. a running wheel with an encoder attached to it).

To be able to control the actuator intelligently the distance between detector and actuator needs to be larger than the DAD. How much larger this distance should be depends on the response time of the actuator. This larger distance ensures that the signal from the detector is received before the intended point of actuation is reached so the control unit on the actuator has time to account for actuator delays.

3.3 Interfacing existing actuators and detectors

The interface definition in chapter 2 can also be used with existing actuators and detectors. Some additional electronics might be required to meet the proposed electronic interface.

Almost all existing actuators use a binary input signal. Not all actuators meet the electrical specifications that are stated in the electronic definition in chapter 2. To meet these specifications signal conversion is needed. The first step is to check if the signal needs to be inverted. This is needed when the actuator needs a logic ‘low’ to engage and a logic ‘high’ to disengage. A simple logic inverter can be used to invert the detector’s signal. The second step is to convert the TTL input signal to the signal level required by the actuator. This can be done in various ways. A simple solution is to use a TTL compatible (solid state) relay.

Detection units have a binary output signal to control an actuator. To meet the requirements of the interface described in chapter 2 the output signal should comply to the TTL specifications. When using existing detection units with non-TTL specifications signal conversion (and possibly -inversion) is needed. A design suggestion is to use an (inverting) output buffer/line driver to generate a TTL compatible signal for the actuator.

3.4 Multiple-row detection units

The interface definition can be used with detection units that sense more than one crop row at a time. Such detection units (will) have a single control line running to each actuator. If the interface definition is applied on these control lines, actuators can be interchanged without any problems.

4. Discussion and conclusions

Sensor based intra-row weed control can be a very effective and environmentally friendly way to remove weeds in the crop row. A detection unit that is able to sense all kind of crops in all growth stages and conditions is a utopian dream just like an actuator that works well in all crops. In practice, different sensing techniques will be used in different crops and different actuators will be used to accommodate for the local, in-field situation. The ability to interchange detection units and/or actuators can be useful to reduce costs and to select the detector-actuator combination best-suited for the job. Therefore there is a need for a standardised interface between detector and actuator.

The interface definition described in this document allows for easy integration of detection units and actuators for intra-row weed control. The interface definition with only two components (detector-actuator distance and signal level) is simple and can be used with almost all detection units and actuators. The described practical implementation of the interface shows that it can also be used on multiple-row detection units and existing actuators and detection units.

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