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Utilising scripting language for unmanned and automated guided vehicles operating within row crops

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ABSTRACT

A flexible high-level control language is an important element in the ongoing task of introducing automated guided vehicles (AGV) to new application domains. A new application domain is row crops, where small AGV's will perform weed control around individual crop plants. This paper defines the requirements and scope of a process- and behaviour-based scripting language needed to control the weeding AGV in an agricultural row crop. The goal is to traverse and cover the whole field with no human auxiliary input during the field operation.

The basis is the transparent and tactical real-time control language (CL) for small mobile robots (SMR). This SMR-CL has been modified to include some necessary motion commands and a supplemental supervisory function to monitor and record the progressive coverage of the field. The control language was then tested by applying it to a scenario representing typical field conditions for row crops.

The construction of a suitable SMR-CL script for use in a field clearly demonstrates the feasibility of adapting behaviour-based control systems to field structures. The conducted case study indicated the importance of including goal-directing modules. Such a module is described here as the 'supervisory field coverage monitor' (SFCM), which acts to coordinate the behaviours. The applicability of this modified SMR-CL has been successfully demonstrated using a vehicle test in a specially designed artificial row crop field.

The analysis of the operational performance verified that it is possible to cover all rows in a field without conducting time-consuming planning procedures.

1. Introduction

Autonomous operation of an inter- and intra-row weeding AGV has to be carried out in a partially unknown environment (e.g. Tillett et al., 1998; Hagras et al., 2002). The environment is also characterised as 'partial-structured' in order to emphasise the notion that some predetermined structure is present in the field.

Generally, an AGV is defined as an encapsulated computer system situated in some environment and capable of carrying out autonomous actions (Wooldridge, 1997).

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The functionality of current commercial AGVs, e.g. vacuum cleaners, lawnmowers and vehicles in industrial applications, encompasses the principle of requiring only minimal skills from the operator of the vehicle. After activation of a simple on/off switch, the vehicle commences operation and completes its task without any further intervention by the operator. Also, the small vehicle concept fulfils the requirements of safe operation, eliminating costly and complicated equipment to address safety issues for the AGV. In most cases, these vehicles adopt a random driving configuration which will not ensure full coverage in an operationally efficient way, as the vehicle may visit the same location more than once (Huang, 2001). This random approach is not regarded as being feasible in the case of an AGV working in an agricultural row crop field where each crop plant has to be visited only once as repeated physical weeding around single crop plants increases the risk of damage to the plant. Also, importantly, the operational performance in terms of time consumption and capacity would be hampered by the inefficiency of a random driving pattern.

Autonomous operations in agriculture have been investigated using different approaches (e.g. Reid et al., 2000; Gray, 2001; Stentz et al., 2002). One approach requires that the autonomous vehicle should follow a predetermined route based on an absolute positioning system such as global positioning system (GPS). The major drawback of this approach is the difficulty in dealing with the dynamics of the environment and the requirement for expensive, accurate and reliable positioning systems. An alternative approach involves the vehicle following a route derived from a local relative reference frame. This relative frame may consist of a row crop camera, different forms of odometry, etc., and allows the vehicle to adjust to the topological characteristics of the environment (Billingsley and Schoenfisch, 1997; Tillett et al., 1998; Hague et al., 2000; Åstrand and Baervaldt, 2002; Sørensen et al., 2007).

A third approach invokes a distributed behaviour-based system (e.g. Kosecka et al., 1997) to control the AGV. This approach may allow a weeding AGV to behave rationally in a row crop field, requiring only minimal *a priori* information and driving relative to the field attributes. Defining the requirements for a high-level control language for autonomous operation in row crop cultures in the inter- and intra-row area as well as close to the crop area would be involved. The control commands may be based on easily recognisable guide-marks similar to those that the human operator normally uses for operating in row cultures. In this way, the AGV motion control is an independent system. The system may also be regarded as a safety-net or fall-back system for more sophisticated planning systems, where real-time kinematic GPS (RTK GPS) or other sensing methods for positioning may fail. The approach using recognisable guide-marks for navigation may be simpler to implement compared with a fully optimised system involving complex global planning efforts. Further, it follows to a large extent the motto: ‘The world is its own best model’, as outlined by Brooks (1991). This statement implies the AGV is navigating in an uncertain and unpredictable environment without planning.

Full utilisation of structures in the field demands that attributes such as field boundary and the row crop structure should be described off-line. However, no heavy data requirement will be needed prior to initialising the AGV. By adapting the field structure to the capability of the AGV, the deliberative part in the AGV control system may be reduced. Such adaptations have been seen in other agricultural applications, e.g. the automatic milking system (AMS), where the positions of the teats on the udder are adapted to the requirements of the AMS by selectivity among the cows (Demont et al., 2001). Other structure-improving measures might include transponder farming, where fields are farmed together to improve and optimise driving patterns (e.g. Demmel et al., 2003).

In order for the AGV to navigate with accuracy within such a semi-structured environment, motion actions have to be generated based on events occurring during the process of performing the task. The control structure has to be flexible in the sense that the required actions (control primitives) are not predetermined in time and space. As an alternative, actions are seen as a function of sensed information from the current environment and the progress of the operation itself. Reactive behaviour must be possible through an adaptation to uncertainty and unexpected events in the environment. The inclusion of a supervisory system for mode generation and goal guidance is also considered to be important (Payton, 1986). However, a ‘job completion’ module will be included in order to enable behaviour sequencing and keeping the goal in sight. This module keeps track of the progress and gives advice with respect to guiding the AGV in its further coverage of the field. In this way, the proposed control system resembles that of a hybrid reactive/goal-directed architecture, as often required by automatic systems (Arkin, 1989; Yavuz and Bradshaw, 2002).

The hypothesis was that the crop structure of a typical sugar beet field forms the basis for a rational weeding operation. Further, it was assumed that an AGV with very limited reasoning and planning capabilities could pass over every row without any *a priori* knowledge except for the inner and outer field boundaries.

The aim was to test the hypothesis by use of simulation, employing a test track, which in this case is a development environment shielded from the hazards of testing in real field conditions and comprising a downscaled field with black lines substituting for the crop rows.

The objective was to adapt an existing AGV to a row crop domain, enabling it to operate using all kinds of structures already present in an agricultural row crop field. The specific objectives of the study were:

(1) to select and describe a typical row crop domain comprising a hypothetical row crop field,
(2) to detail the basis for selecting a potential AGV platform together with its control language,
(3) to describe basic system components and functionalities of the weeding AGV,
(4) to propose modifications and extension to the selected AGV,
(5) to design a case offering different challenges in terms of motion complexity in order to simulate the use of the modified control programming,
(6) to design a comprehensive test of the physical performance of the vehicle while incorporating the derived modifications, and