Development of a technology demonstrator for the enhancement of embedded software design considering mechatronic systems in agriculture

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Abstract: Modelling, simulation and optimisation of modern agricultural implements and machines can be generally approached as tasks related to design of mechatronic systems. Establishing of appropriate simulation models, capable to emulate the relevant properties of the subsystems and their interaction, allows the development under laboratory conditions without necessity to have continuous access to the affected system or physical components. In order to enhance the further development and optimisation of the embedded software of a mobile diagnostic and performance analysis system, intended for redundant mobile data acquisition parallel to the machine controller, a low cost technology demonstrator was developed. The demonstrator enables the emulation of adequate analog and digital signals corresponding to the modules of the device for automated attaching of the supporting wires for hops, as well as reliable and repeatable introduction of different type of phenomena within the deterministic control cycle.

Keywords: model based design, technology demonstrator, embedded software, mechatronic systems in agriculture

1 Introduction

The adoption of embedded technologies while developing agricultural machines and implements is still a challenging task. Nevertheless, the development based on a modular approach allows maximising the flexibility by creating reusable, scalable and replaceable components which can be easily tested and assembled, significantly affecting the way of the design process. Modelling, simulation and optimisation of modern agricultural implements and machines often consider design of mechatronic systems consisting of integrated mechanical, electrical, and software subsystems [Go12], [Go15b]. Within the innovation project (see Acknowledgments) a prototype of a device for automated attaching of the supporting wires for hops has been developed [Go12]. During the development and testing of the prototype, the possibilities and advantages of the application of a redundant mobile data acquisition system for further data analysis were identified and discussed [Go13], [Go15a]. Accordingly, important information considering the system performance, failures and their causes, if outage occurred, is available. For automated analysis an off-line tool was developed in Scilab. In the following project (see Acknowledgments) a zero-series device, as well as an online diagnostic system implemented on

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an embedded real-time controller CompactRIO based on LabVIEW FPGA, LabVIEW Real-Time (National Instrument) and previously developed algorithms will be designed. One of the main advantages of the online solution is immediate diagnostic of failures and outage causes.

To assure the highest area capacity, the machine user would like to carry out the work with minimum mistakes, failures or outage, moving with optimal speed near to maximally available. Considering these prerequisites, the control software of the device is optimised. Because of the high complexity of the machine and the parameters such as roughness of the soil surface, atmospheric conditions, quality of the wire, dirt, vibration and shock affecting the sensors accuracy and drift etc., irregularities need to be considered during the automatic execution of the software. The irregularities cannot be easily predicted and thus, their observation under real condition is monotonous and often time-consuming. Hence, a low cost technology demonstrator was developed, enabling the emulation of the adequate analog and digital signals corresponding to the modules and their functionality within the device for automated attaching of the supporting wires. The demonstrator should provide an adequate supporting environment for development and testing of the embedded software for the mobile diagnostic and performance analysis system under laboratory conditions. With the demonstrator reliable and repeatable introduction of different type of phenomena (above described irregularities) within the deterministic control cycle is possible.

2 Materials and methods

Device for automated attaching of the supporting wires
The actuators of the device are hydraulically driven and controlled by a programmable logic controller (PLC). The attaching process can be carried out in manual or automatic mode while the tractor moves forward along the longitudinal cable in a hop garden.

Diagnostic and performance analysis system
When connected, the diagnostic and performance analysis system and software on CompactRIO runs logically parallel to the PLC and acquires data from sensors mounted to the device hydraulics, as well as the physical analog and digital inputs and outputs (AI/AO DI/DO-s) of the PLC. The online diagnostic system is intended to be used and accompany the work under harsh environmental condition and therefore must be adapted to the different needs of the users (e.g. technician responsible for the maintenance; personal responsible for service of hydraulics, electronic as well as mechanic; farm manager etc.) at an early stage of the project. The design of the software architecture allows simple introduction of additional functionalities and features.

Technology demonstrator
In order to allow further development of the software, keeping the process straightforward, the technology demonstrator (see Figure 1) was modularly designed in order to-generate several types of common signals (e.g. 24V DO [digital switch, etc.]; 0-10V AO [linear position etc.]; incremental encoder DO with different resolution).

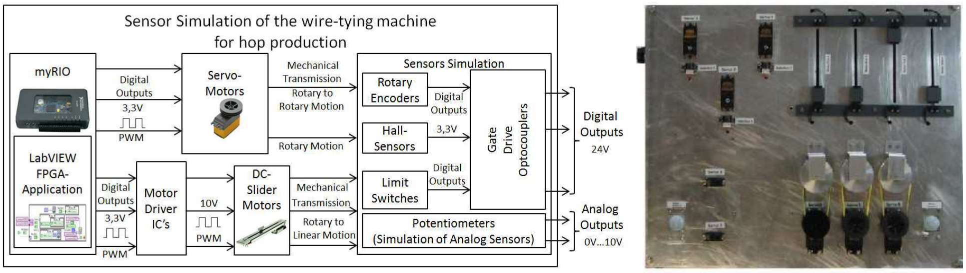

Fig. 1: Schematic diagram and the front panel of low cost technology demonstrator

The hardware solution consists of a group of servo and slider motors controlled by NI myRIO (National Instruments) and a group of different sensors. The positioning of the motors is controlled by a software solution designed in LabVIEW FPGA and implemented on the FPGA of the myRIO. The parameters can be changed and the positioning command released using the human machine interface (HMI) on the host PC. The motors are controlled with pulse width modulation (PWM). A self-designed printed circuit board (PCB) allows signal amplification in order to control the positioning of the slider motors in both directions via L293E driver ICs. Rotary encoders connected to the motors via belt drives and hall sensors, have different resolution and are implemented for detecting the position of the servo motors. Slider potentiometers are used for detecting the position of the slider motors. The slider potentiometer can be positioned between two end positions with limit switches. The output voltage of the potentiometers is ranged between 0V to 10V. The output of the rotary encoders and hall sensors is 3.3V digital signal. These signals are amplified to 24V, regarding to the typical output of industrial sensors, using the fast ACPL T350 optocouplers (rise time = 15ns; fall time = 20ns). Furthermore, the optocouplers provide galvanic isolation between the power circuit on which myRIO and sensors are connected and the digital outputs of the simulator.

3 Results and discussion

The demonstrator can emulate different signal constellations, allowing investigation of particular phenomena, which sometimes are not simple to detect on the real machine, or are not typical for the steady-state operating mode. Due to the modularity, the outputs can be easily reconfigured providing adaptability in term of changing I/O requirements as well as the required signal combination. Oppositely to not fully deterministic testing by simulation running under e.g. Windows, the use of the demonstrator is important for more rigorous testing of determinism of the embedded software. Particularly, testing of the developed or optimised parts of the embedded software can be more easily carried out by reliable and repeatable introduction of different type of phenomena within the deterministic control cycle. Furthermore, software in the loop (SIL) test [Zsm11] can be carried out in parallel.

4 Conclusions

Based on the preliminary results, the application of the technology demonstrator can be positively evaluated in terms of a faster and more reliable development without necessity to carry out the development directly on the device for automated attaching of the supporting strings in hop gardens. While developing the embedded software for the diagnostic tool, the capabilities of the demonstrator will be comprehensively tested. The project contributes to improving the design process of mechatronic systems in agriculture and the achieved results can be implemented in further projects.

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