Field-Robot-Based Agriculture: "RemoteFarming.1" and "BoniRob-Apps"

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Abstract

Based on the autonomous field robot BoniRob, which was developed for plant phenotyping, the authors have created an enhanced platform BoniRob (V2). The design of BoniRob (V2) considers two main improvements: At first the robustness for continuous outdoor use is increased and secondly the robot now makes available a reusable platform that can serve for multiple agricultural purposes. The combination of the platform BoniRob (V2) and application modules ("BoniRob-Apps") is comparable to the classical combination of a tractor and an implement. In order to demonstrate this new concept, the authors have implemented three BoniRob-Apps, which can be integrated in BoniRob (V2) via defined mechanical, electrical and logical interfaces.

The research project RemoteFarming.1 goes even beyond the accomplishment of a specific task by a robot and demonstrates the integration of the BoniRob (V2) platform into agricultural processes. For that purpose innovative agricultural engineering is combined with web-based communication technologies. The target is to develop a robotic mechanical weed control system which integrates a human user as remote worker in the process. The robotic weed control system is used for intra row weed treatment in carrots at BBCH-scales 10 to 20 in organic farming. This task is today conducted by hand.

Introduction

In recent years a variety of field robot prototypes have been proposed. They cover several applications, such as scouting and sampling, precise variable rate application of pesticides and fertilizers as well as autonomous weeding [1][2]. However, until now there is no commercial application of autonomous field operation in agriculture available. This is partly due to open issues regarding safety and legal requirements of autonomous operations [3].Another problem of the presented prototypes for autonomous field robots is their conception as single-purpose robots, despite there being several applications with market potential [6]. As the single-purpose concept leads typically would lead high costs due to a low workload over the year (specific tasks are required over only a short period of time), the systems are not economically feasible yet. To overcome this barrier a new concept for a multipurpose field robot is shown here.

Multipurpose field robot platform BoniRob (V2)

The BoniRob (V2) platform has been designed as an improved version of the BoniRob crop scout, which has been announced by the authors [5]. The BoniRob (V2) is shown in Fig 1.

Fig.1: BoniRob (V2) during a RemoteFarming.1 field trial

It was reengineered with focus on robustness and reusability. This manifests in increases of power supply by the electrical generator, continuous and peak torque at the wheel drives as well as chassis clearance (Table 1).

Table 1: Technical figures of BoniRob (V2)

	BoniRob crop scout	BoniRob (V2) platform
Power of electric generator	2.0 kW	2.6 kW
Battery's capacity	110 Ah	170 Ah
Continuous drive torque (per wheel)	55 Nm	70 Nm
Peak drive torque (per wheel)	110 Nm	240 Nm

As it can be seen in Fig.1, the height adjustment of the entire robot body was replaced by vertically fixed arms for each wheel, which can be rotated in the horizontal plane for adjustment of track width and centration of the robot body over the row to be treated. The hydraulic height adjustment was replaced by a manual, mechanical height-adjustment module frame. Furthermore, all other hydraulic drives were replaced by electrical systems.

The BoniRob-App concept

Using the multipurpose field robot platform BoniRob (V2) as a carrier, supplier and base for multiple BoniRob-Apps can be compared to the traditional combination of a single tractor with multiple implements. BoniRob-Apps can be integrated into the platform using defined mechanical, electrical and logical interfaces.

The module frame of 0.77 m x 0.75 m in the centre of the robot allows mechanically attaching the BoniRob-App (Fig. 2). The mounting height can be adjusted in a range of 0.4 m.

The electrical connection is set up using a custom plug. This provides energy supply to the BoniRob-App and different voltage levels (230V AC, 24 V DC, 12 V DC, 5 V DC). Moreover, it allows linking the emergency stop infrastructure of platform and App, such that even the App can stop the entire robot in case of emergency.

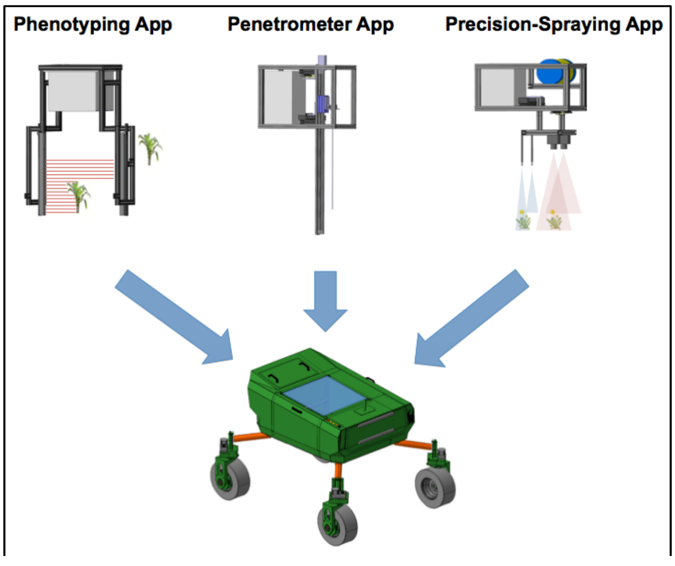


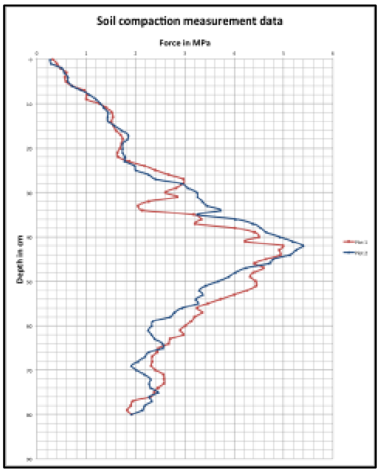
Fig. 2: Multiple BoniRob-Apps can be used in the same platform

Also, the custom plug sets up a Gigabit-Ethernet connection to the host-computer on BoniRob (V2). The entire communication infrastructure on BoniRob (V2) and between platform and the Apps is designed using Ethernet and *ROS* [4]. A sequence controller with 2 levels opens the way for distributed drive control of the robot. In the row the App (level 2 sequence controller) can access the drive control. On the headland the platform (level 1 sequence controller) holds the access to the drive control and runs the turn procedure of the robot. This allows switching the access to the drive depending on the state including letting the App control the drive train of the robot in properly defined situations. Again, this can be compared to a tractor-implement combination. In recent years in the field of *Tractor Implement Management* advances have been made towards control of the tractor by the implement in specific situations, because the implement and its sensors are closer to the process and more specifically adapted to it. This also shows that BoniRob-Apps are more than just tools to be used with the BoniRob (V2) platform but smart combinations of mechanical and electrical systems together with process- and application-specific intelligence.

BoniRob-Apps: Demonstrating examples

In order to demonstrate the new concept, the authors implemented three BoniRob-Apps:

<u>Penetrometer App</u>



This module integrates a mechanical actuator into BoniRob (V2). A penetrometer is included for soil property measurements down to depths of about 80 cm. The amount and the positions of the measurement points can be defined prior to an automatic run, thereby using linear motors within the module and GPS. As compared to (typical) manual applications of a penetrometer, the automatic system shows constant characteristics and allows replications for a large number of measurements (Fig. 3).

Fig. 3: Chart of soil compaction pressure

<u>Phenotyping App</u>

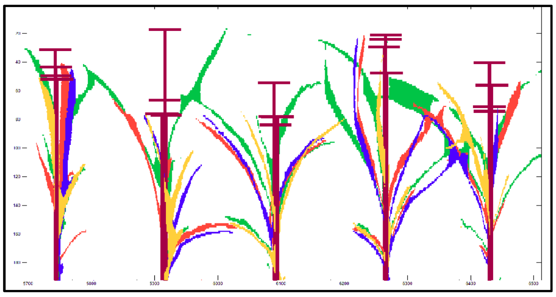


Fig.4: Re-identification of plants

Plant characterization based on multi-sensor applications including morphological and spectral characteristics. Several sensors are applied, such as time-of-flight cameras, light curtains or spectral imaging. In particular, re-identification of plants and thereby allowing monitoring plant growth of single plants will open various opportunities including single plant management zones in field trials ([8], Fig.4).

Precision-Spraying App

Fig. 5: Spraying nozzles

A camera-based solution for local chemical weed control has been applied. The camera is used to detect green areas and the spraying nozzles are controlled such that plant protection or herbicides are only applied in areas that actually contain plants. This technology has the potential for a tremendous reduction of applied pesticides as compared to a homogeneous treatment (Fig. 5).

Process integration of the robot in RemoteFarming.1

The three mentioned BoniRob-Apps have shown the flexibility of the BoniRob-Platform. As part of the research project RemoteFarming.1 another BoniRob-App has been built for mechanical weed control. However, in this case BoniRob and the App are integrated as one part of a more complex environment, including web-based communication, server, web-client and a human remote worker. The App has an actuator for mechanical treatment of weeds (Fig. 6). Furthermore, it uses synchronously triggered cameras and lighting units at different wavelengths which can capture high-contrast images of the plants [7]. The cameras and lightning units are mounted in a shaded space underneath the robot. The shading can be seen in Fig.1.

In the first part RemoteFarming.1a, the detection of weeds is performed in a web-based approach solely by the remote worker. He/she marks the weeds in images captured by the robot on the field. Afterwards positions are transferred back to the robot via Internet and mobile networks (Fig. 6). Then the mechanical actuator of the robot moves to those positions in the field, which have been marked in the respective images, and eliminates the weed plants.

In the second part RemoteFarming.1b, this system will be enriched with weed/crop classifiers where – based on the results of automatic (image-) data processing - the user will get a suggestion of possible weeds marked in his view and he can confirm or modify these suggestions before the weed will be treated.

Fig. 6: Web-based communication between the mechanical weed control system and the remote worker's web client GUI

The central idea of RemoteFarming.1 is to integrate a human user as remote worker into the weed control process. Thus, it drastically reduces the complexity of the problem in heterogeneous environments by not aiming to solve it using a fully autonomous system but integrating human-machine interaction as crucial component in the process. In the second part RemoteFarming.1b, the robust infrastructure developed in RemoteFarming.1a will be enriched by shared data processing and reusing gathered data for model improvement. This will not lead to a fully but increasingly autonomous and still robust weed control system.

Conclusion

Laboratory and first field trials of all technical modules have been performed. Moreover, switching of the modules as a basic process for a multipurpose robot is shown. The smart, exchangeable BoniRob-Apps and the extensive process integration of the robot in RemoteFarming.1 demonstrate the potential of the multipurpose field robot BoniRob (V2).

Acknowledgements

The project RemoteFarming.1 is supported by funds of the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the innovation support programme. The project SmartBot is supported by EU INTERREG(EDR and EUREGIO).

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