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Creating a Comprehensive Software Framework for Sensor-Driven Precision Agriculture

Abstract.

Robots and GPS-guided tractors are the backbone of smart farming and precision agriculture. Many companies and vendors contribute to the market, each offering their own customized solutions for common tasks.

We present an open framework that provides interoperability of equipment from different manufacturers. Combined with a suitable middleware configuring all components attached to a chassis, it becomes possible to quickly leverage the investment of a robot.

Providing smart configuration management, we enable the integration of components like cameras, sensors, AI hardware, actuators, protocols or communication devices. Support of real-time protocols ensures the framework's ability to control actuators with sub-centimeter accuracy as required by real-world precision farming tasks. Since it offers high flexibility and is by design almost arbitrarily expandable, our system can be used on anything from a small golf cart sized robot to large, high-throughput farming equipment. The framework is suitable for various precision and smart farming applications like e.g. planting, weeding, spraying, watering or simply monitoring. The unified software environment offers standardized protocols and works out of the box with different hardware in a plug-and-play manner. An end-user of a farming robot will be able to switch from modular irrigation units to weeding tools and thus, change the robot's task from watering to weeding with only little configurations and no reprogramming efforts.

Keywords.
Precision Agriculture, Robotics Framework, Sensing, Real-Time Weeding, AI

Motivation

Robots and GPS-guided tractors are the backbone of smart farming and precision agriculture. Many companies and vendors contribute to the market, each offering their own customized solutions for common tasks. These developments are often based on vendor-specific, proprietary components, protocols and software. Many small companies that produce sensors, actuators or software for niche applications could contribute their expertise to the global efforts of creating smart farming solutions, if their components could easily be integrated with modules and platforms of other vendors.

Standardizing Interfaces

In order to integrate components and software by different vendors, it is necessary to create a framework that supports the coexistence and interoperability of the various existing protocols, electrical signals and even mechanical interfaces. Combined with a suitable middleware configuring all components attached to the chassis for a certain task, it becomes possible to leverage the investment of a robot or GPS-guided tractor quickly, since they can be repurposed for other tasks more easily. This can help trigger end-users' decisions to get started with smart farming technology by allowing them to build on and expand their already existing equipment to various new applications.

General Concept

The majority of smart farming tasks can be generalized as a sensor-actor-architecture as shown above. This setup consists of a number of sensors acquiring data as the vehicle is moving, a real-time processing unit making decisions based on the data and a number of actuators being controlled by these decisions. This can e.g. be a mechanical interaction (weeding) or spot spraying or surveying.

Open Framework

We present a framework for smart farming solutions for self-guided agricultural machinery that is specifically designed to be open to components from any vendor. By defining a standard set of mechanical and electrical interfaces regearing between tasks becomes a matter of minutes.

Configuration management

Apart from regearing the equipment the main aspect of task switching is a matter of configuration. This includes device-specific parameters, plant-specific algorithms and other data related to the new task. To ensure user acceptance this process must be as simple as possible for the end user.

Our solution uses smart configuration management to enable the integration of components like cameras, sensors, AI hardware, actuators, protocols or communication devices. Support of real-time protocols ensures the framework's ability to control actuators with sub-centimeter accuracy as required by real-world precision farming tasks. Since it offers high flexibility and is by design almost arbitrarily expandable, it can be used on anything from a small golf cart sized robot to large, high-throughput farming equipment. The framework itself is task-agnostic and can thus be used for various precision and smart farming applications like e.g. planting, weeding, spraying, watering or simply monitoring.

The unified software environment offers standardized protocols for specified field tasks and works out of the box with a wide range of different hardware in a "plug and play" manner. An end-user of a farming robot will then be able to switch from modular irrigation units to chopping tools and thus, change the robot's task from watering to weeding with only a few configurations and no reprogramming efforts.

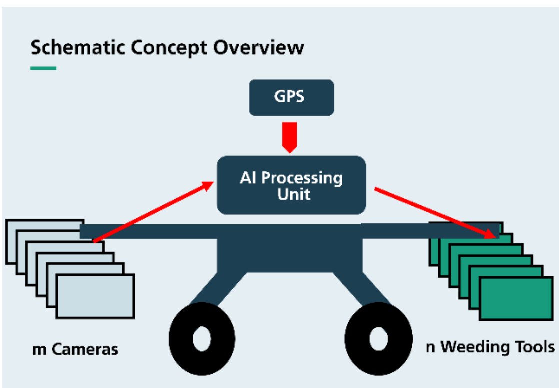
Integration of new sensors and actuators is greatly simplified by avoiding complicated existing robotic frameworks and by offering lightweight protocols.

IP management built-in

Integration of hardware and software components from different vendors poses the challenge of unifying various IP licensing concepts. By offering a flexible IP management concept this can be achieved in a transparent and easy to understand way for the end-user.

Pilot projects

Using the first iteration of this system, a fully autonomous in-row weeding robot for sugar beet plants using custom AI-based sensors and in-row weeding tools was built. The system differentiates between sugar beets and weeds using AI and controls the weeding tools in real-time with 1 cm accuracy. This is only one exemplary use-case to demonstrate the already existing potential of our versatile software framework.



Left: Schematic Concept Overview
Right: Pilot project for AI-based autonomous in-row weeding

Conclusion

We are actively working with various vendors integrating their products - from robots to sensors to actuators - into our framework. In this way, we are prepared to make sensors from the smallest robot to largest agricultural machines ready for practical use.

As a non-profit institute, we seek cooperation with all those who share our goals: Making smart agriculture viable for the coming decades. We also want to be a point of contact for the agricultural machinery industry and support them in expanding their market share for new technologies.

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