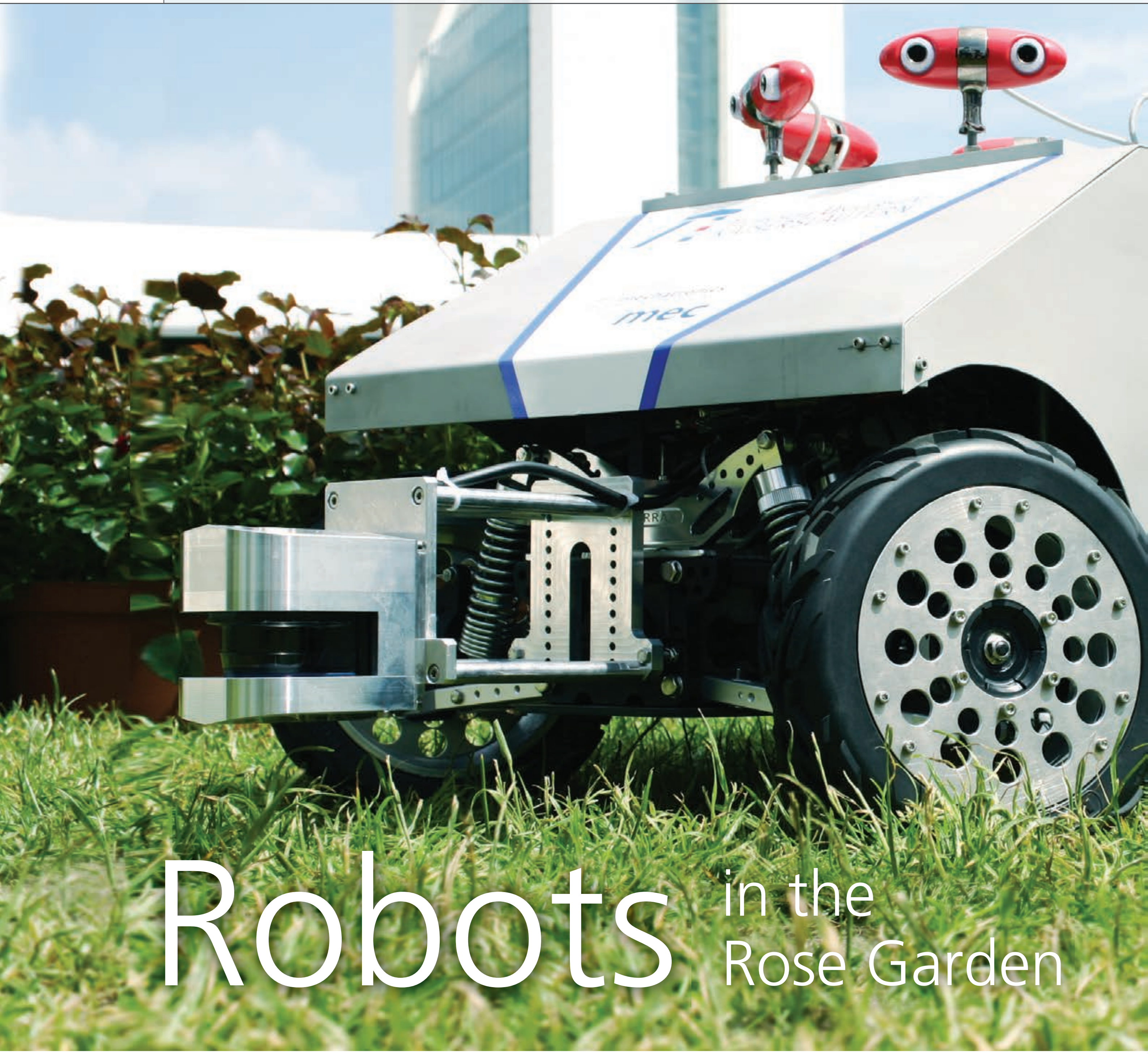


Robots in the Rose Garden

Limited resources, climate change and a rapidly growing world population make efficiency and sustainability the biggest challenges in horticulture and agriculture. Using the latest technologies is the key to meeting these challenges. Year for year, a team of students from the Institute of Mechatronics in Mechanical and Automotive Engineering at the University of Kaiserslautern, and many other teams, participate in the Field Robot Event, an international competition for autonomous field robots, giving a detailed picture of the new generation of agricultural technology.

Autonomous Vehicles for Horticulture and Agriculture

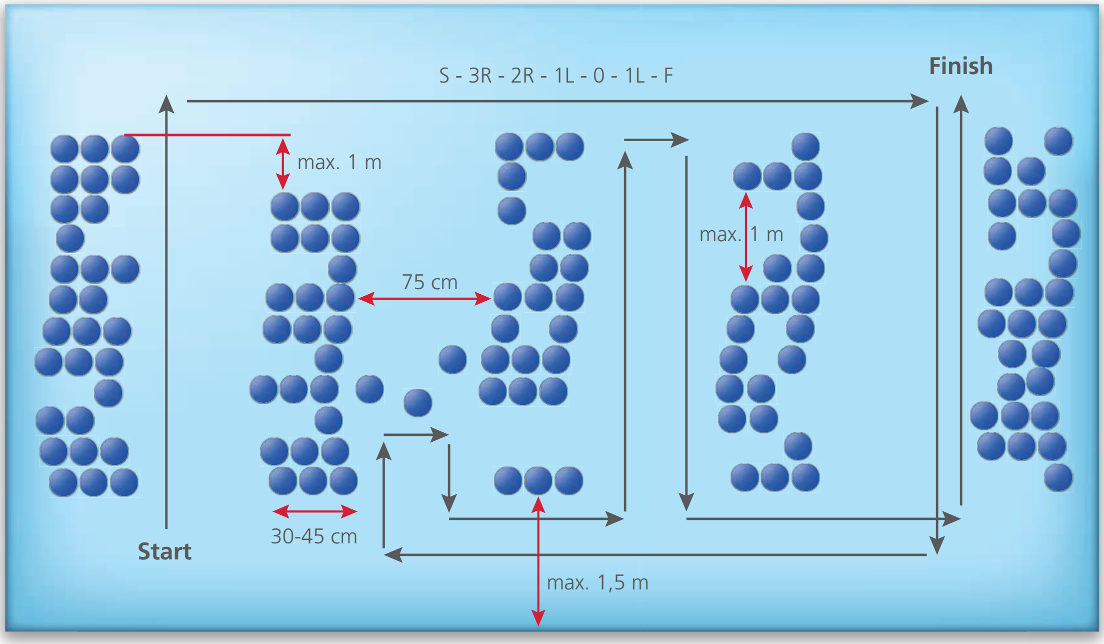


Figure 1: A task of the Field Robot Event 2012 was to drive autonomously through rows of plants in order to complete a given route.

> "Because dSPACE's MicroAutoBox II plus Embedded PC combines the proven tools of hardware-related ECU development with the flexibility of a PC, it was an excellent platform for our autonomous vehicle."

Roland Werner, University of Kaiserslautern

A Small Revolution

Intelligent sensors, GPS-based automatic steering systems with centimeter-level accuracy, robots and autonomous vehicles are the next major step in agricultural engineering. To meet these enormous technological challenges, new creative approaches and interdisciplinary thinking are needed. The Institute of Mechatronics in Mechanical and Automotive Engineering (MEC) at the University of Kaiserslautern set up a team of students to take on this task. Together, the students developed an autonomous vehicle for field use.

The Competition

The highlight of the team's year on the project was participating in the Field Robot Event, an annual international field robotics competition, held in 2012 in Venlo (Netherlands) as part of the Floriade (international garden show). The overall task of the Field Robot Event was to let a vehicle navigate autonomously through rows of plants (figure 1). Missing plants, and curved and blocked rows made it difficult for the vehicles to move along. On their way, the vehicles were required to perform additional tasks related to agriculture. The assessment of the teams was based on the distance traveled in 3 minutes, with bonus points for completed tasks and penalty points for plant damage and manual intervention. A particular challenge of last year's Field Robot Event was finding, picking up and returning a randomly chosen, specially marked plant among rows of rose pots.

The World from the Vehicle's Eye

A large number of sensors give vehicles the ability to recognize their environment (figures 2 and 3). One

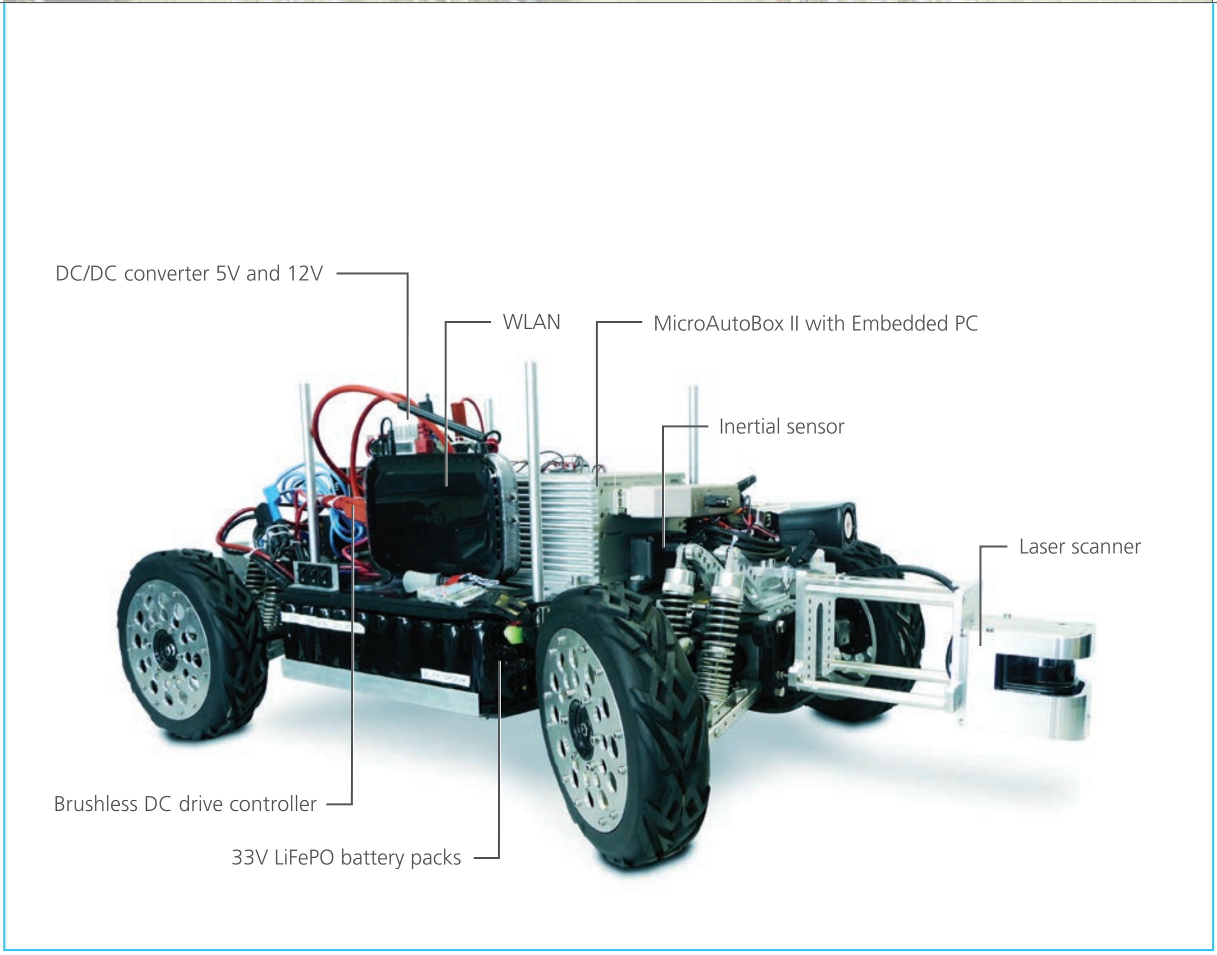


Figure 2: The main components of the autonomous vehicle developed by students from the Institute of Mechatronics in Mechanical and Automotive Engineering (MEC) at the University of Kaiserslautern.

important component for autonomous driving is a set of two laser scanners mounted on the front and back of the vehicle. Delivering a 240° field of view in one scanning plane, the scanners allow to detect obstacles in the vehicle's surrounding environment. For the turning at the row's end, the yaw rate measured by inertial sensors and the resulting calculated vehicle orientation is crucial. Located on the vehicle roof, six stereo webcams with a total 360° field of view allow to find the marked plant and provide information on the vehicle's distance to the plant. In addition to these sensors for autonomous navigation, the vehicle carries a WLAN interface and an R/C receiver for development and testing purposes.

Four-Wheel Steering and Drive

Unpaved surfaces, obstacles and narrow turns between rows are challenges for the vehicle's actuators. Four servo motors allow for steering all wheels individually. A central brushless DC drive with 2 kW power and a permanent four-wheel drive provide the necessary force at the four tires. An intelligent power converter supplies the drive from the vehicle's 33 V LiFePO battery pack.

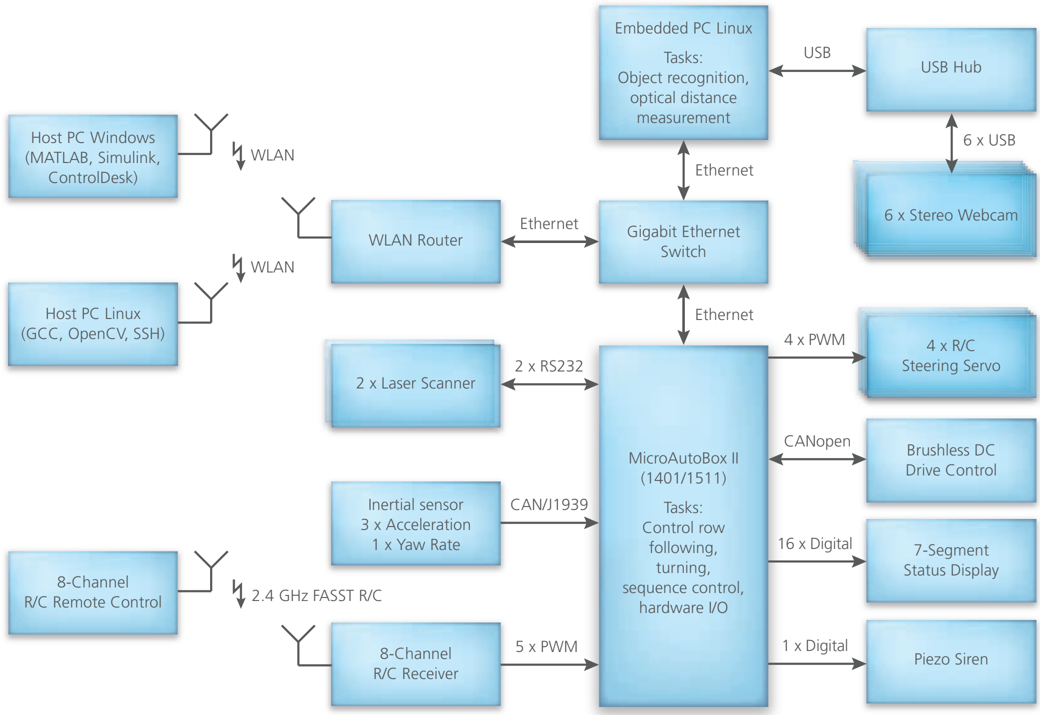


Figure 3: Block diagram of the autonomous vehicle's sensors, signal processing and actuators.

Distributed Signal Processing I: Real-Time Control with MicroAutoBox II

For signal processing and actuator control, the vehicle uses the advantages of two worlds. Hardware-oriented closed-loop control tasks are handled by a MicroAutoBox II in real time. The algorithms for row detection, path tracking and headland turns, plus the sequence control of the entire vehicle are essential parts of the software running on MicroAutoBox II. The multitude of I/O interfaces makes it easy to connect to all different kinds of sensors and actuators (figure 3). MATLAB®/ Simulink® provide a proven develop-

Figure 4: Object recognition via OpenCV with a marked plant in the original image (left: cylinder in red, blue and yellow), recognized color regions (right: rectangles in red, blue and yellow) and identified plant marking (right: white rectangle).

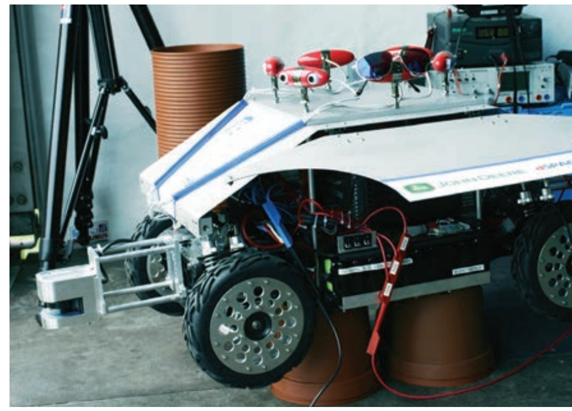
ment environment for these tasks; and ControlDesk® enables fast, reliable and convenient system configuration and diagnostics.

Distributed Signal Processing II: Image Processing with Embedded PC

Image processing and machine vision are centrally important tasks for autonomous vehicles. The free C/C++ software library OpenCV has a comprehensive collection of up-to-date algorithms available for various platforms, including Windows® and Linux.

The combination of MicroAutoBox II and Embedded PC make integrating the image processing tasks into the overall system quite easy. The internal Gigabit Ethernet switch and UDP/IP guarantee rapid communication between MicroAutoBox II and Embedded PC running Linux. One particular challenge of the Field Robot Event 2012 was to have the autonomous robot identify a randomly chosen, specially marked rose pot and stop in the immediate vicinity of the pot. The marking selected for the pot was a cylinder with streaks of red, blue and yellow (figure 4). Recognizing the markings is performed sequentially, with the first step being the identification of image areas containing a high proportion of the marking's colors. Next, the arrangement of these areas is used to differentiate between the searched markings from other random image components in the environment. The size of the discovered markings and the depth information of the stereo image serve as the base values for measuring the distance between the vehicle and marked plant. ■

Roland Werner
University of Kaiserslautern



Conclusion and Outlook

The Field Robot Event 2012 was the second stage for the development of the MEC vehicle. In comparison to its debut the year before, the team improved its placement, moving from 10th to 6th place out of 18 teams. In particular, the platform shift to dSPACE MicroAutoBox II was a positive improvement. The reliable, proven development tools allowed the team to focus their attention on function development. Furthermore, the combination of MicroAutoBox II and Embedded PC was especially beneficial because the team could implement the hardware-oriented applications with real-time requirements and a variety of I/O interfaces without having to sacrifice the flexibility of a PC. The next step for the students from the University of Kaiserslautern will be to enter their further optimized vehicle at the Field Robot Event 2013, taking place at the Czech University of Life and Environmental Sciences (CZU) in Prague.

Roland Werner
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