Weedy – a sensor fusion based autonomous field robot for selective weed control

M.Sc. Dipl.-Ing. (FH) Ralph Klose [1], Dr. Johannes Marquering [2],
M.Sc. Dipl.-Ing. (FH) Marius Thiel [1], Prof. Dr. Arno Ruckelshausen [1]

[1] University of Applied Sciences Osnabrück / Competence Center of Applied Agricultural Engineering – COALA, Osnabrück

[2] B. Strautmann & Söhne GmbH & Co. KG, Bad Laer

Abstract

The field robot Weedy is a complete system integration for a sensor fusion based autonomous mechatronic system for selective weed control. The system integration contains the development of strategies and the implementation of the mechanics, electronics, and software for the two main tasks, the autonomous navigation and the weed control. The combination of different sensor systems and the algorithms for the tasks are based on a sensor fusion concept. As a result of this system integration, a robot was created which is able to travel autonomously through maize fields and which is equipped with sensor systems and an actuator enabling the robot to perform weed controlling actions in maize rows.

Introduction

Recent developments in electronics, sensor technologies and mechatronics have opened new research options in the field of small autonomous agricultural field robots. While robot contests – such as the Field Robot Event [1] – already demonstrate future options and the need for interdisciplinary approaches, products are not yet available. Recently the authors have proposed a new concept for a modular autonomous robot for weed control within row cultures [2]. In this paper the realization of the system within a cooperation of a University of Applied Sciences (Osnabrück/Germany) and a company of agricultural technology (Amazonen-Werke) is presented.

The modular robot system has to be able to navigate autonomously in maize fields. This means that the robot has to be able to drive over maize rows without damaging plants and without any kind of human interference. To achieve robust navigation, the row guidance of the robot has to function for either straight or curved rows even if the soil is wet or if plants are missing in the row. Another important part of the autonomous navigation besides the row guidance is the autonomous turn at the end of one row into the next.

FIGURE 1: FIELD ROBOT WEEDY

The second task of the robot is the autonomous selective weed control. According to the definition of weed to be everything green within the field except maize plants, the robot has to be able to detect plants in the inter row space and it has to identify maize plants and all other plants in the intra row and close-to-crop area.

In order to fulfill the boundary conditions for the two main tasks of the field robot, autonomous navigation in a maize field and weed control, alternative strategies for the implementation of the mechanics, electronics and software into a mechatronic systems have been evaluated.

System structure of the field robot Weedy

The system architecture splits up into five main parts: the robot control system, the navigation control system, the weed control system, the speed and steering control system and the safety system. Each of these four systems contains the relevant electronics, mechanics and software for its special functionality. These five main systems of the robot are linked via a CAN-bus-system. Graphical user interfaces were developed to enable the user to interact with the robot in a comfortable way and to ensure electronic documentation. These user interfaces can establish a connection to the robot via CAN bus or a wireless LAN link using the access point implemented into the robot architecture.

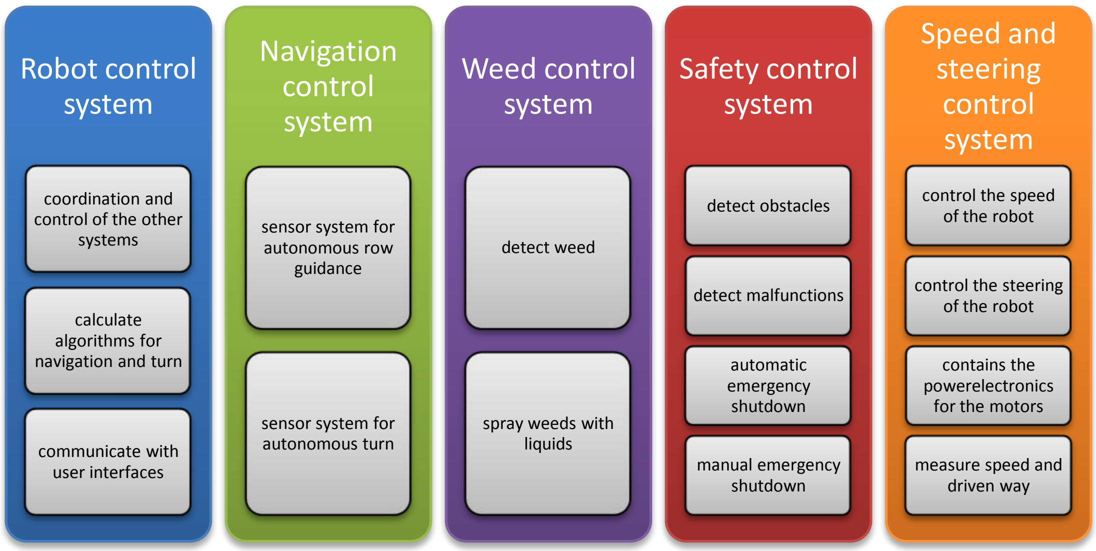

FIGURE 2: SYSTEM STRUCTURE OF THE FIELD ROBOT WEEDY

Cameras, optical and acoustic distance sensors as well as other low-cost sensors (such as position encoder or angular sensors) are used for navigation and weed detection. The combination of different sensor systems and the algorithms for the tasks are based on a sensor fusion concept to get a higher robustness for navigation and the weed control and to compensate potential unfavorable or interfering influences on a single sensor system. Therefore, different sensor types that use different physical effects for the measurement are integrated into the control systems. Another demand is to have a constant navigation performance of the robot even if row conditions change. To keep the quality of the row guidance constant, the sensor fusion concept needs to be flexible and adjustable. On the one hand it is possible to turn single sensors off and on the other hand it is possible to set priorities for the different sensors.

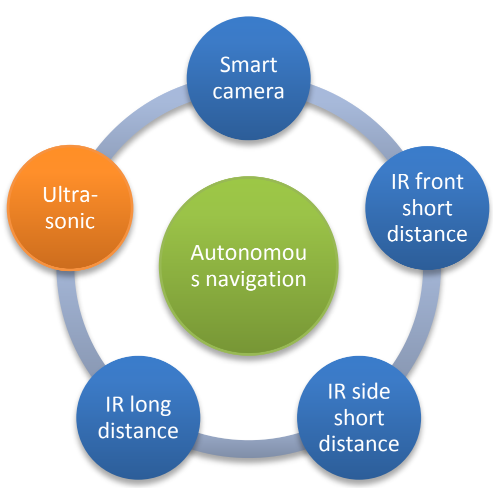

FIGURE 3: SENSOR FUSION CONCEPT FOR THE AUTONOMOUS NAVIGATION

For the weed control it was decided to use a spray system instead of a mechanical actuator. An advantage is that weed control can be performed by one kind of actuator instead of different mechanical systems which would be required to cover all three areas of the maize row. For the three different areas, it is necessary to have three different sensor and spray systems for the detection and the treatment of the weed within the left and right row and in the center of the robot. For the weed control actuator, it is very important to always be centered over the plants of the middle maize row to keep a constant distance to the plants. Since the robot does not always drive perfectly in the middle of the row when passing curves, the weed control actuator needs to be moveable. As the actuator for the weed control unit an assembly of a linear drive, used for centering the actuator over the maize row, and a combination of a pump and different sprayers is used.

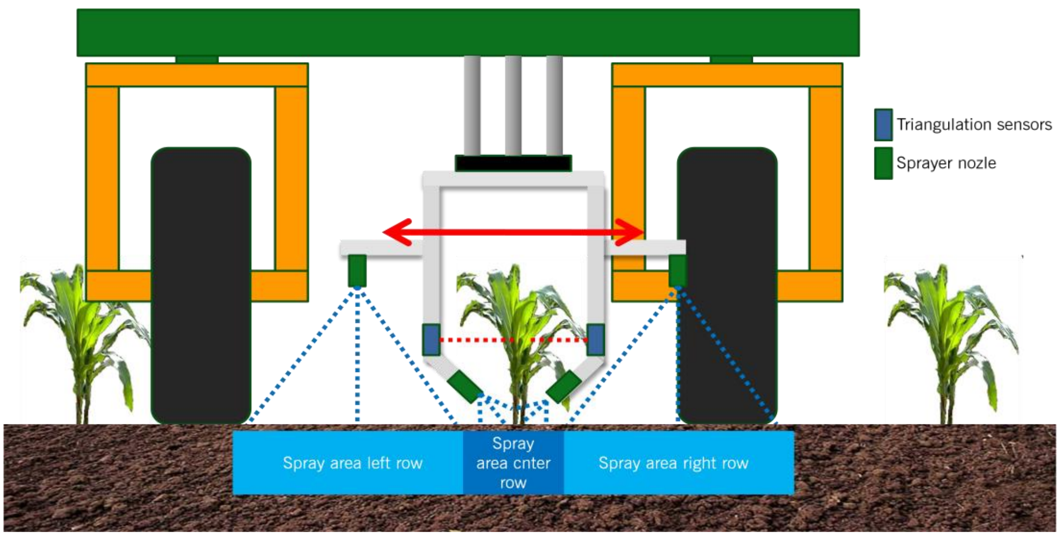

FIGURE 4: WEED CONTROL ACTUATOR OF THE ROBOT WEEDY

The weed control system splits up into two different parts: the inter-row weed control and the intra-row / close-to-crop weed control. The two areas “intra-row / close-to-crop“ will be treated as one, since they are very close to each other and since it will not be possible to detect weed in the close-to-crop area with this system which results of the sensors used. However, this system can be used as a base for further developments of a close-to-crop weed detection system using for example complex image processing algorithms. The weed detection for the inter-row weeds will be done by the analysis of the data of two CMUcam3s. As mentioned above, the weed within the inter-row area is defined as every plant visible with a green color. Since the contrast between the green color of the weed and the dark brown color of the soil is very high, it is possible to use the color-tracking feature of the CMUcam. According to this, weed is detected within the inter-row space as soon as the CMUcam can track the defined color of the weeds.

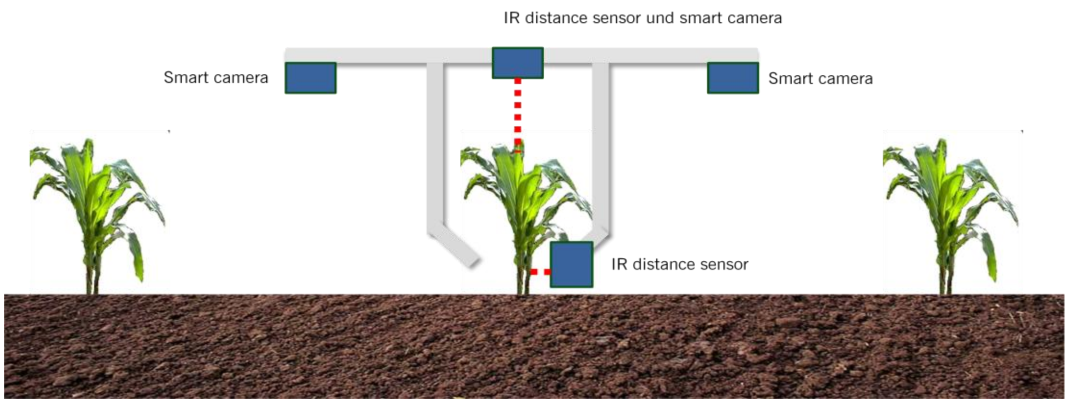

FIGURE 5: SENSOR SYSTEM OF THE WEED CONTROL ACTUATOR

The detection of the intra-row / close-to-crop weed is done by a combination of different sensors that are integrated in a sensor fusion concept. The first sensor system used to detect the maize plants is a combination of two laser triangulation sensors. The first sensor is placed in the middle of the weed control actuator facing down to the plants. With this orientation, it is able to measure the height profile of the plants and the weed. This information is combined with the result of the measurement of the laser triangulation sensor placed at the side of the weed control actuator measuring the thickness of the plants shafts. To obtain a higher reliability for the weed detection, another indicator for a maize plant is needed. Therefore, the line statistic packets of the CMUcam are analyzed. Figure XXX shows the different positions of the mean value of every line recorded with the CMUcam. In this case, the CMUcam calculates minimum and maximum values as well as the position of the mean value of the color to track within every line of the image.

The example in figure XXX shows the positions of the mean values for different maize plants and dandelions (representing the weed). To detect the weed within the maize plants it is now necessary to take a look at the changes of the position of the mean value. Figure XXX shows the result of the calculation of the position change of the mean value compared to the prior position. It can be seen that the rate of the position change is higher in case of weed appearing in the image. According to this, the standard deviation of the mean value positions of every line can be used as a third indicator for a maize plant.

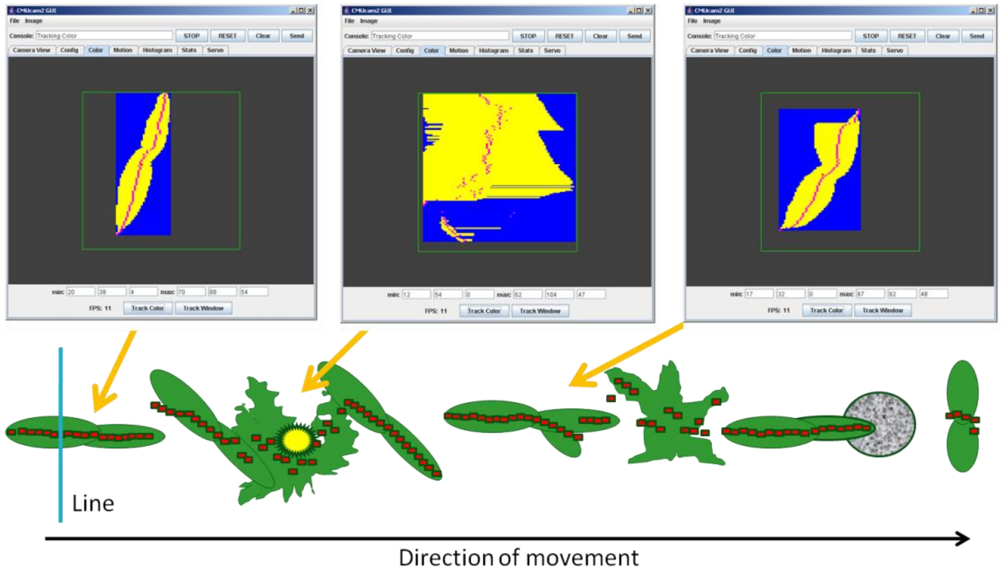

FIGURE 6: WEED DETECTION WITH THE STATISTIC FEATURE OF THE CMUCAM

Moreover, a safety concept has been integrated from the beginning in order to avoid that the robot harms humans or animals. The robot is able to detect obstacles in its surrounding ("ultrasonic wall"), emergency buttons have been integrated, malfunctions of the system software result in a shutdown and signal lights show the status of the robot operation.

Conclusion

As a result the field robot Weedy was developed which is able to navigate autonomously through maize fields being able to perform weed control in the inter-row, intra-row and close-to-crop area of the maize row. The turn in the headland is also included. The system integration as well as the operation of the complete system has been successfully tested under laboratory and field conditions for the first time.

[1] Henten, E.J. van, Hofstee, J.W., Müller, J.. Ruckelshausen, A., 2007. The Field Robot Event – An International Design Contest in Agricultural Engineering. In: Fountas, S., Aggelopoulou, A., Gemtos, F., Blackmore, S. (eds.), 2007, Proceedings of the 6th European Conference on Precision Agriculture, 3-7 June 2007, Skiathos, Greece, Paper nr. 88, 6 pp.

[2] Ruckelshausen,A.; Klose,R.; Linz,A.; Marquering,J.; Thiel,M.; Tölke,S.: "Autonome Roboter zur Unkrautbekämpfung"; Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, Sonderheft XX, 173-180, 2006.