Sensor fusion based navigation of the autonomous field robot Maizerati

Multisensor-basierte Navigation des autonomen Feldroboters Maizerati

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Summary: The autonomous field robot Maizerati has been developed for the participation of the international Field Robot Event. Major tasks for the competing vehicles are the navigation in between maize rows and a U-turn at the end of the rows. The concept of sensor fusion has been applied by integrating a smart camera, optical distance sensors, ultra-sonic sensors and a gyroscope sensor chip. The system architecture is based on embedded microcontrollers. A graphical user interface (GUI), a touch display and WLAN technology have been developed for the learning period. The field robot Maizerati has shown to be successful for autonomous navigation within a broad range of field conditions.

Keywords: Field Robot Event, autonomous robots, sensor fusion, electronics, maize.

Kurzfassung: Der autonome Feldroboter Maizerati wurde für die Teilnahme am internationalen Field Robot Event entwickelt. Wesentliche Aufgaben im Wettbewerb sind die Navigation zwischen Maisreihen und eine Wende am Ende der Reihe. Es wurde ein Multisensor-Konzept realisiert, unter Integration einer intelligenten Kamera, optischen Abstandssensoren, Ultraschallsensoren und einem Gyroskop-Chip. Die Architektur des Systems basiert auf systemintegrierten Mikrocontrollern. Eine grafische Benutzeroberfläche, ein Touch-Display und WLAN-Technologie wurden für die Lernphase implementiert. Der Feldroboter Maizerati konnte bei einer Vielzahl von Feldbedingungen erfolgreich autonom navigieren.

Deskriptoren: Field Robot Event, autonome Roboter, Multisensorsysteme, Elektronik, Mais.

1. Introduction

The development of robots for agricultural applications has become increasingly important, however, due to varying boundary conditions the complexity of such systems is rather high (VAN HENTEN et al. 2006, RATH and KAWOLLEK 2006). In order to stimulate innovations as well as the education of students the international Field Robot Event (FRE) has been introduced by Wageningen University (The Netherlands) where student groups develop autonomous robots in order to satisfy the tasks of the competition (MUELLER et al. 2006). Based on experiences of the authors during the development of the field robot optoMAIZER for the FRE 2005 (KLOSE et al. 2006), the new robot Maizerati has been developed (see figure 1) for the FRE 2006 in Hohenheim/Germany. The concept of sensor fusion is applied, which has already been introduced by the authors earlier for weed control applications (RUCKELSHAUSEN et al. 1999).

Figure 1: Autonomous field robot Maizerati in the maize field

2. System Architecture

The system architecture of the autonomous vehicle Maizerati (see fig. 2) is based on microcontroller technology combined with the sensor fusion concept. This concept uses the information of 19 sensors of eight different types for the tasks of the Field Robot Event 2006. These tasks include the row guidance of the robot, the turn at the end of the rows, the hole detection, the detection of a corner flag and the ball counting. A smart camera called AVRcam with onboard image processing has been integrated. The sensor information is processed with the two microcontrollers (C167 and MB90F340). The preprocessed sensor data of the Fujitsu controller is sent to the C167 controller via a CAN-Bus. To handle the time-critical tasks of the robot like navigation and WLAN-communication, the real-time operating system RTXtiny has been integrated.

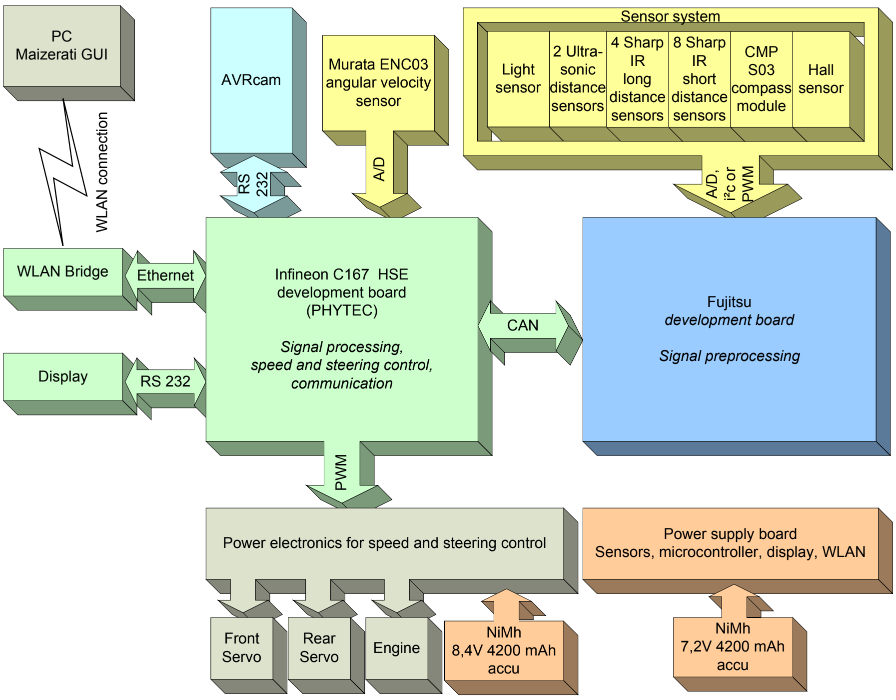

Figure 2: Architecture of the autonomous field robot Maizerati

The different sensors have been arranged in a sensor fusion concept that gives the opportunity to combine different sensors or sensor types for one specific task as shown in figure 3. This results in a higher flexibility and security for the whole system. Another aspect of the sensor fusion concept is the growing complexity of the system.

Figure 3: Sensor fusion concept of the autonomous field robot Maizerati for the Field Robot Event 2006

To give the user an easy way to interact with this complex system and to maintain it, a touch display and WLAN have been integrated. The touch display has been implemented for direct (and fast) user access, such as starting the robot or selection of navigation strategies or parameters. In combination with the graphical user interface the WLAN connection can be used for remote controlling the robot, to perform data acquisition, to update the software, for choosing algorithms, to change parameters during runtime and to read out the camera image. Another useful feature is the build-in error notification. These two user interfaces reduce the complexity for the user of controlling the real-time algorithms of the senor fusion and actuator system.

3. Navigation

The navigation in the row is based on an optical system (AVRcam and IR distance sensors), an acoustic system (ultra sonic sensors) and a mechanical system (flex sensors). With this combination of different sensor systems, it was necessary to prioritize the sensor information. The two flex sensors have the highest priority because of their main task to avoid collisions with the plant. If the flex sensor were touched, the system has to react immediately.

The second priority is given to the long distance IR sensors (Sharp GP2Y0D02YK) and the ultra sonic sensors (SRF10), which have been integrated for security reasons. These sensors are able to measure long distances and offer the possibility to look a long way forward along the maize rows. They are very useful for an early curve and collision detection. To calculate the resulting steering direction, the row is divided into five zones. The position of the robot in the zones is calculated with the sensor information of the IR and ultra sonic distance sensors. Each of these zones stands for a predefined steering direction and strength. The third priority belongs to the most important sensor for the navigation, the AVRcam. With its ability to track different color blobs, it can be used for a smooth navigation within the row. The navigation algorithm has already been used by the authors for the autonomous robot optoMAIZER in combination with a CMUcam2 (KLOSE et al. 2006). For this algorithm, the camera image is divided into virtual windows (fig. 4).

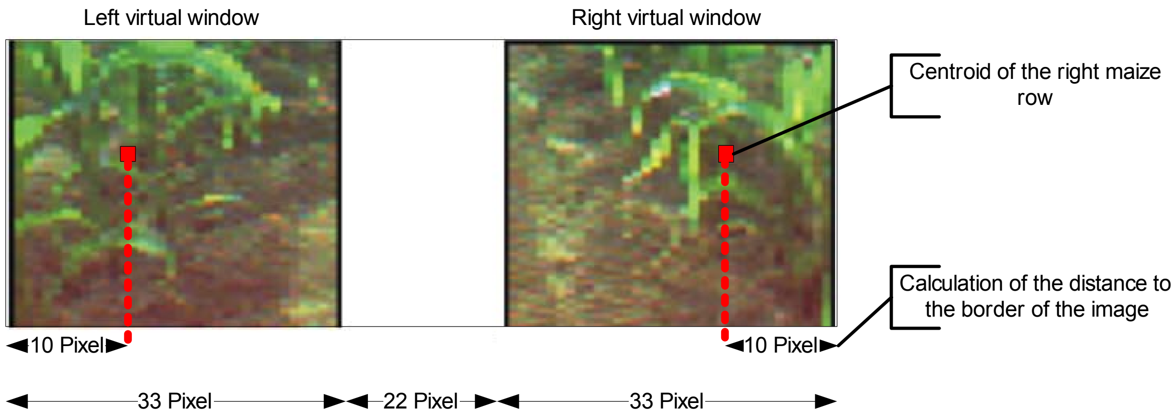

Figure 4: Navigation with the CMUcam2

As figure 5 shows, the left maize row is located in the left virtual window and the right maize row is located in the right one. With this arrangement of the windows color tracking for both sides is possible and the calculation of the centroids of the maize rows for the predefined colors can be performed.

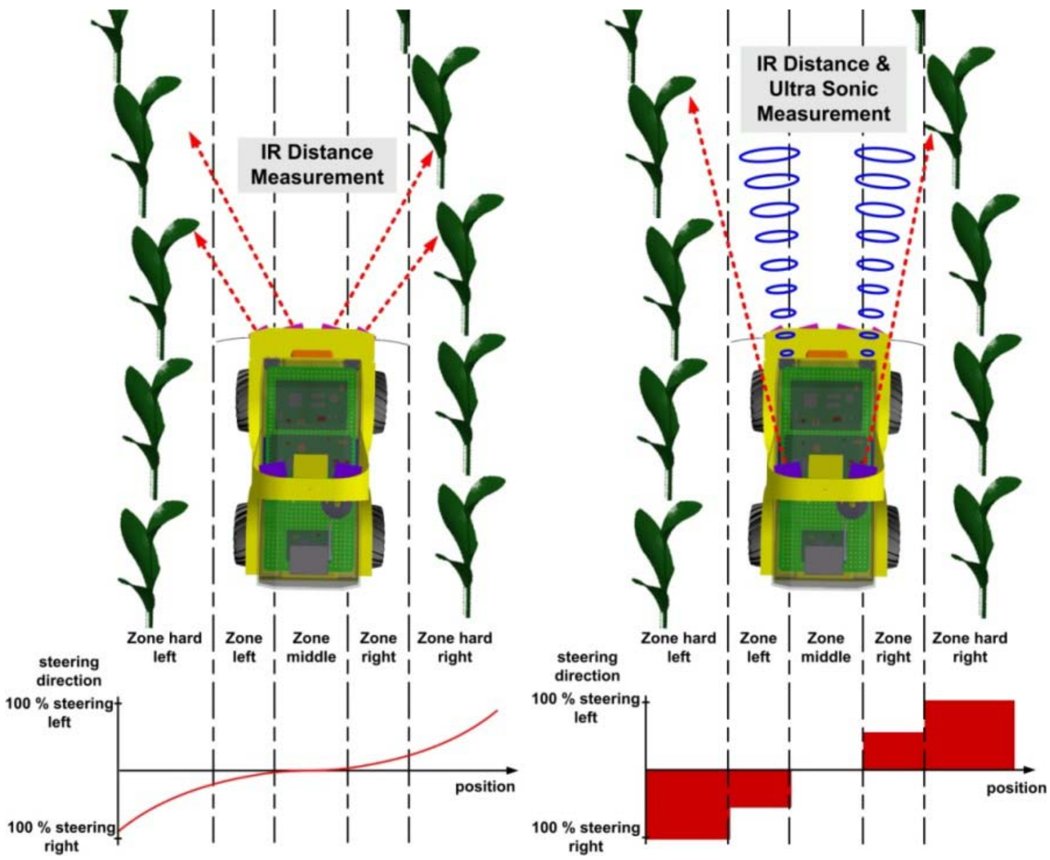

Figure 5: Navigation strategy using IR distance and ultra sonic sensors

If the distances of the two centroids with respect to the camera position are compared, a resulting steering direction for the robot can be calculated. The lowest priority belongs to the short distance IR-sensors (Sharp GP2D12). The measured distance to the plant within the row is separated into five zones in which the robot can be located. The exact position within the row is determined by the use of the four front IR distance sensors. With this data, the robot is assigned to one of these zones. Depending on the determined location, a decision is made concerning the steering direction.

As figure 5 shows there are two IR sensors used for each side. The difference in position and angle is recalculated concerning the known structural differences. This redundant sensor secures that the robot is able to measure the distance to a plant in most of running time. The implemented algorithms offer the possibility to determine the position of the robot if there are only plants available on one side of the row.

Because of the need to make an exact turn at the end of each maize row into the next but one row, a gyroscope sensor (Murata ENC-03) has been integrated into the system. With this sensor, it is possible to control the turn process by measuring the turn angle. To make a turn, a curve with a predefined radius is driven until an angle of 180° is measured. With the navigation algorithm for the long distance IR sensors it is possible to enter the row without touching the plants. Afterwards the row navigation is continued.

4. Conclusion

The sensor fusion concept has been successfully applied to an autonomous field robot for the Field Robot Event. Varying selectivities of the different sensors support a robust navigation under complex field conditions. The development of small robots for competition purposes serves as an impact for innovations in the field of agricultural engineering.

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