Fachhochschule Osnabrück
University of Applied Sciences

Navigation And Detection

# Autonomous system for **N**avigation **A**nd **D**etection in agrícultural environments

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## Abstract

The autonomous field robot NAD has been developed at the University of Applied Sciences Osnabrück as a master thesis. The robot is based on the robotic platform called *profibot* of the Fraunhofer Institute of *Intelligente Analyse- und Informationssysteme.* The centre of the system architecture is a mini PC using a Windows XP operating system combined with an iCONNECT development suite. The iCONNECT software is a comfortable integrated development environment for fast and block oriented programming of industrial applications. The main function of this software is the data acquisition of the sensor information and the calculation of resulting speed and steering commands for the robot.
To give a high robustness to the autonomous row guidiance within the maize rows the robot is equipped with ten distance sensors, used for measuring the distance between the robot and the plants. With the need to make an exact turn at the end of the row it was necessary to integrate a gyroscope to measure and control the turn angle. To detect and calculate the position of the yellow golf balls, simulating dandelions, a smart camera was installed.


**Figure 1:NAD**

**KEYWORDS**
Field robot, Platform Profibot, iCONNECT, WLAN Ad-hoc connection

# 1 Introduction

The robot NAD has been developed for the special tasks of the filed robot event 2007 in Wageningen. The tasks were as described below:

1. The robot should cover as much distance as possible in 3 minutes time while navigating between curved rows of a maize field, making a head-land turn and returning in the adjacent row.
2. The robot should cover as much distance as possible in 3 minutes time while navigating between straight rows of maize plants. The robot should be able to follow a certain pre-defined pattern over the field. At various places in the maize field, plants will be missing in either one or both rows over a length of maximally 1 m. A head-land of only 1.5 m will be available for turning.
3. The robot should cover as much distance within 3 minutes time while navigating between straight rows of maize plants. In the maize field randomly distributed artificial weeds - yellow golf balls have to be detected. Detection of a ‘weed’ should be demonstrated by producing a clear signal such as a flash-light or a sound. Additionally, a ‘weed-killing’ operation should be performed on the ‘weed’.
4. Robots are invited to perform a free-style operation. Fun is important in this task but agricultural relevance is emphasized. One team member has to inform the public about the idea. **[Fieldrobot]**

# 2 Hardware

The main advantage of the concept is to use an existing robot platform which has to be modified for the tasks of the field robot event 2007. As this platform a robot, developed by the Fraunhofer Institute of *Intelligente Analyse- und Informationssysteme,* called *profibot* (figure 2.1) was choosen. The robot was selected because of the following features:

- easy to handle lightweight framework
- robust and user-friendly drivetrain
- very high agility

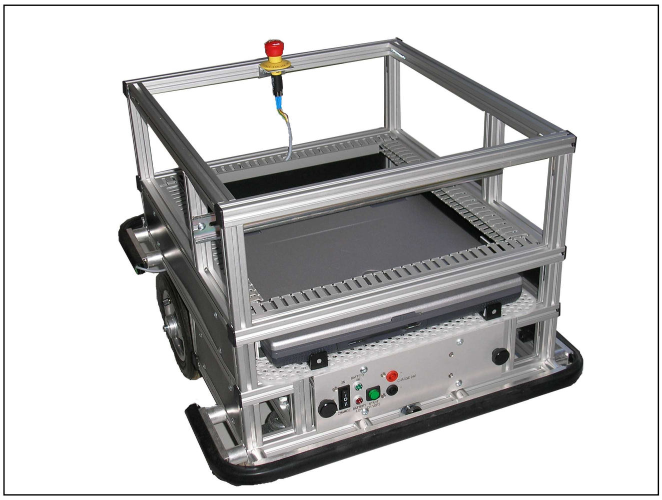

**Figure 2.1: Profibot**

## Project profibot

The profibot project has been initialized by the fraunhofer institute. It is used as a mechatronic system for training and teaching purposes for industrial education. The main goal of this project is to make the educational fields of mechatronics, mechanics, electronics and computer science more practical and interesting. Additionally the understanding for technical systems will grow which can be an additional qualification for further job-live.

## Profibot system

Each of the two frontwheels is driven by one of the two maxon dc motors with mounted gearboxes. Steering is automatically done by speed difference between these two front wheels. The engines are equipped with a rotary encoder for the speed and steering control.
The two engines are powered by two 12 V lead accumulators. The robot is also equipped with a sensor which can detect collisions. If a collision is detected, the robot stops immediately.

The centre of the profibot system architecture is a laptop mounted onto a drawer (figure 2.2). The controlling of the robot is done by the iCONNECT software.

Additionally, the following equipment belongs to the profibot:

- USB Web Cam – Typehoon Easycam 1.3 Mpix
- USB speaker – Sigma SP3000
- USB Experiment Interface Board – Vellman K8055
  (2 analog input, 2 PWM output, 5 digital input, 8 digital output)
- USB Joystick – Saitek Cyborg EVO Wireless

In the future, a robot arm will be mounted on top of the profibot (figure 2.3)

**Figure 2.2: Profibot with laptop [Profibot]**

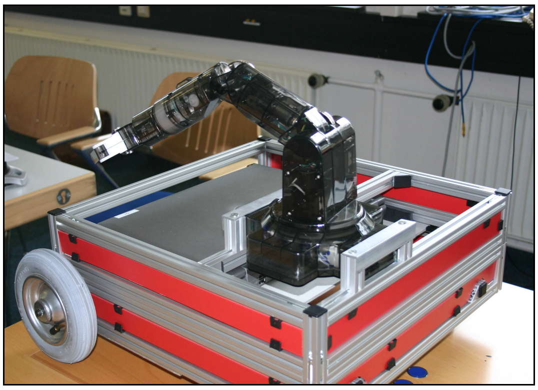

**Figure 2.3: Profibot with robot arm [Profibot]**

### Profibot modifications

Profibot has been designed for indoer applictions. As a consequence the platform has to be change strongly for the field robot event. The following modifications have been done to the profibot:

1. Wheels were changed to bigger ones to be able to drive in rough terrain
2. gear transmission ratio was changed to raise to maximum speed
3. the width of the robot was reduced to make it fit into the maize rows
4. additional sensors were added for the autonomous navigation
5. to reduce the size of the robot a mini pc instead of a laptop was installed
6. an enhanced measuring board was installed to gather the sensor data
7. an additional microcontroller board was used for the analysis of the CMUcam2, the Ultra-Sonic and the Gyroscope signals

## 2.1 Sensors

The robot uses ten distance sensors and two flex sensors combined as redundant sensos systems in a sesor fusion concept to give a higher robustness to the autonomous navigation between the rows. To make a controlled turn at the end of the rows, a gyroscope was integrated. A camera is used for the detection of the yellow golf balls.

### Sharp IR distance sensors

The main sensors for the navigation of the robot NAD are eight low-cost IR distance sensors. Four of these sensors are long distance sensors (type GPY0D02Y), appropriate with the direction to the front, are used for the detection of curves.
The other four Sharp IR sensors are short distance sensors (GP2D12). Their main task is the calculation of the position of the robot within the rows.

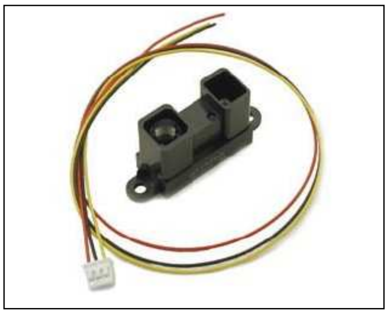

**Figure 2.4: IR distance sensor [Acroname]**

### Ultrasonic Sensors

Additionally two Ultrasonic distance sensors (SFR8) are used for the navigation. With their position at the side of the robot, they are able to measure the distance to the maize plants. The main advantage of ultrasonic sensors compared to the IR-distance sensors is the big spot measured.

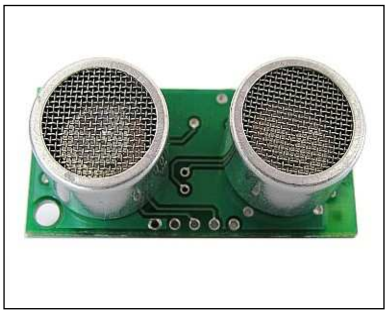

**Figure 2.5: Ultrasonic sensor [RT]**

## Flex sensors

For security reasons, two mechanical sensors have been attached to the front of the robot. These flex sensors consist out of strain gauges which change their electrical resistance when they are touched/bend by the collision with a maize plant.

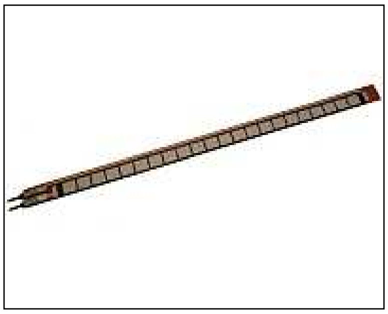

**Figure 2.6: Flex sensor [MM]**

## Gyroscope

The gyroscope is a sensor that can measure the angular velocity of the robot. To calculate the exact direction/angle of the robot, an integration of this angular velocity is done by a microcontroller. The sensor was integrated into a circuit board together with filter circuits to reduce the noise of the signal and to compensate temperature changes. **[optoMAIZER 2005]**

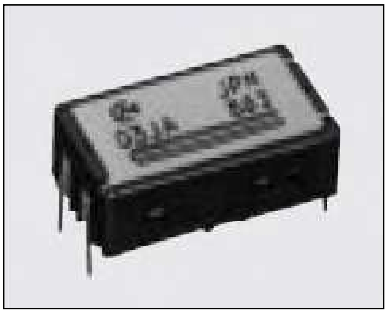

**Figure 2.7: Gyroscope**

## CMUcam2

The CMUcam2 is a smart camera with onboard image processing. Its main feature is to perform tracking of predefined color blobs within different virtual windows and to send the result as reduced data over a serial RS2323 link. It is used to detect the yellow color of the golf balls and to calculate their position within the rows. The CMUcam2 has already been successfully used for the autonomous robots Eye-Maize, optoMAIZER and Maizerati. **[optoMAIZER 2005] [Maizerati 2006]**

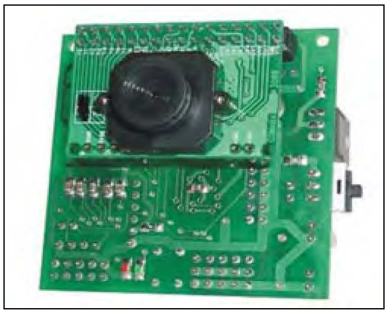

**Figure 2.8: CMUcam2**

## 2.2 User interface

### Touch display

The touch display is used as an easy way for the user to communicate with the robot without the need to know the whole system in detail. The user can choose different operation modes for the different tasks of the field robot event and have a look at process data. During the navigation the number of the next row to drive into is displayed and parameters can be changed.

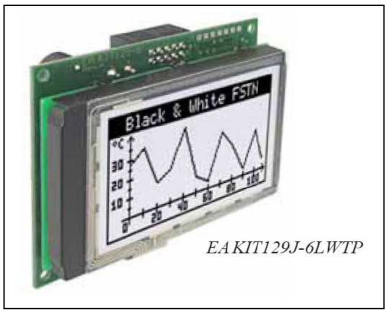


**Figure 2.9: Touchdisplay [E.A]**

### Wireless LAN Dongle

The PC-board which is integrated into the robot system is equipped with a wireless LAN dongle to make it accessible from another computer without the need to use any cables. The WLAN link (ad-hoc) is also used to establish a remote desktop connection using Ultra VNC. The connection is very useful during the test period to make changes to the software without the need to connect a screen, mouse and keyboard to the PC board.

## 2.3 Controller

### Mini ITX motherboard

Because of the reduced size, weight and cost a mini ITX PC motherboard with a VIA EDEN 1,2 GHz CPU was used instead of a Laptop. The supply voltage for the pc board is generated by a Marex Mini ITX 60W power supply and a DC to DC converter which uses the 24 V of the two lead accumulators.

Technical data:

- VIA EDEN 1,2 GHz Prozessor
- 512 MB 533MHz DDRII RAM
- 10/100 LAN on Board
- 8x USB
- 2x COM
- 1x Firewire

**Figure 2.10: Mini ITX Motherboard [Reichelt]**

### Labjack U12

The measuring board called “Labjack U12” produced by Meilhaus performs the data acquisition of the eight IR distance sensors and the two flex sensors. The measuring board can be connected to the PC via USB and it can be easily used with iCONNECT.

I/Os:

- 8 analog inputs
  (used for 8 IR distance sensors)
- 2 analog outputs
  (not used)
- 20 digital I/Os
  (2 used for flex sensors)

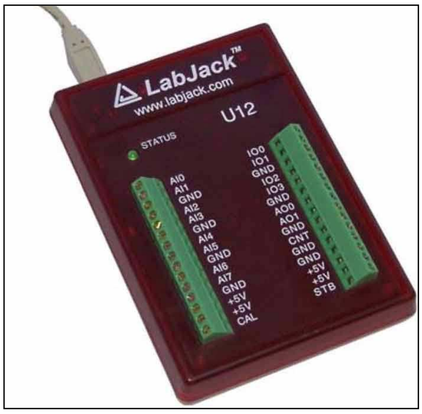


**Figure 2.11: LabjackU12 [Labjack]**

### Glyn Evaluation Board MB90F340/860

The Glyn Evaluation Board is necessary for the data acquisition of the gyroscope, the CMUcam2 and the ultrasonic sensors. These sensors can’t be used with the U12 measuring board because of the need to perform a fast signal preprocessing or the need of the sensors to be connected over a serial RS232 link (CMUcam2) or an i²c link (ultrasonic sensors). The Glyn Evaluation Board was chosen because of the existing experience in working with the Fujitsu MB90F340 microcontroller. The preprocessed data is transferred via RS232 to the PC and can be used for further processes in the iCONNECT environment.

Features oft the microcontroller

- 1xCAN Interface
- UART
- 24MHz
- 512K Flash
- I²C (400Kbit/s)
- A/D Converter (24 input channels with 10 or 8- bit resolution)

**Figure 2.12: Glyn Evaluationboard [Glyn]**

# 3 Software

The operating system installed on the PC is Windows XP. For the data acquisition of the sensor signals the software iCONNECT was installed. The software iCONNECT is a comfortable integrated development environment for a fast block orientated programming. Figure 3.1 shows the block diagram of NADs software.

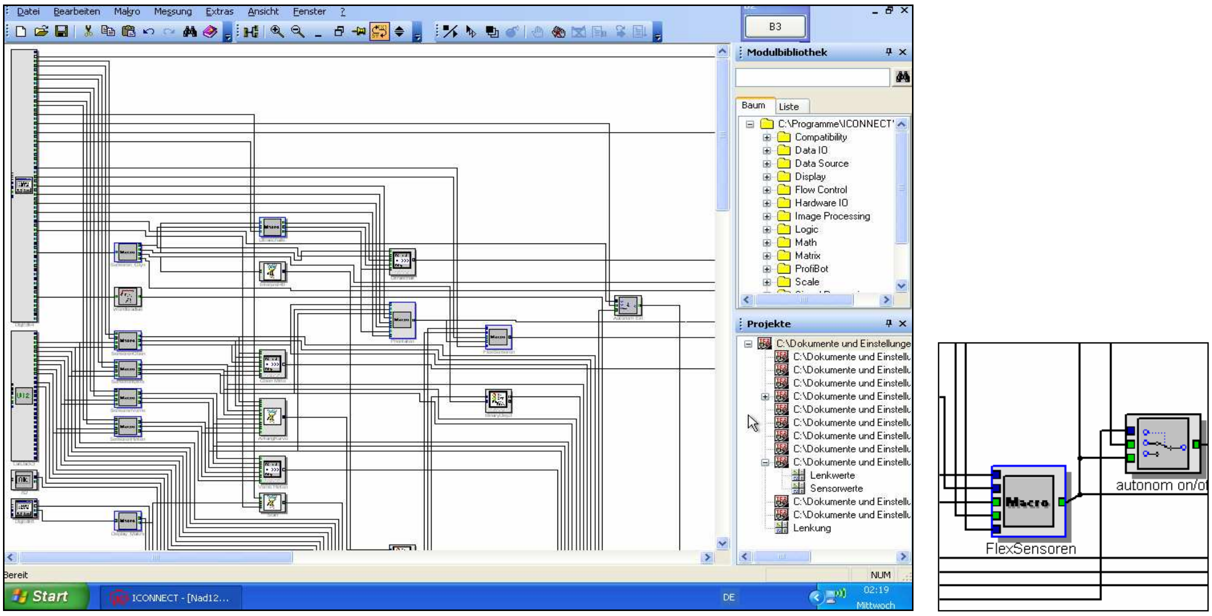


**Figure 3.1: Block diagram of NAD**

Figure 3.2 shows the sensor data of the eight IR distance sensors gathered with the Labjack measuring board and visualized with the iCONNECT software.

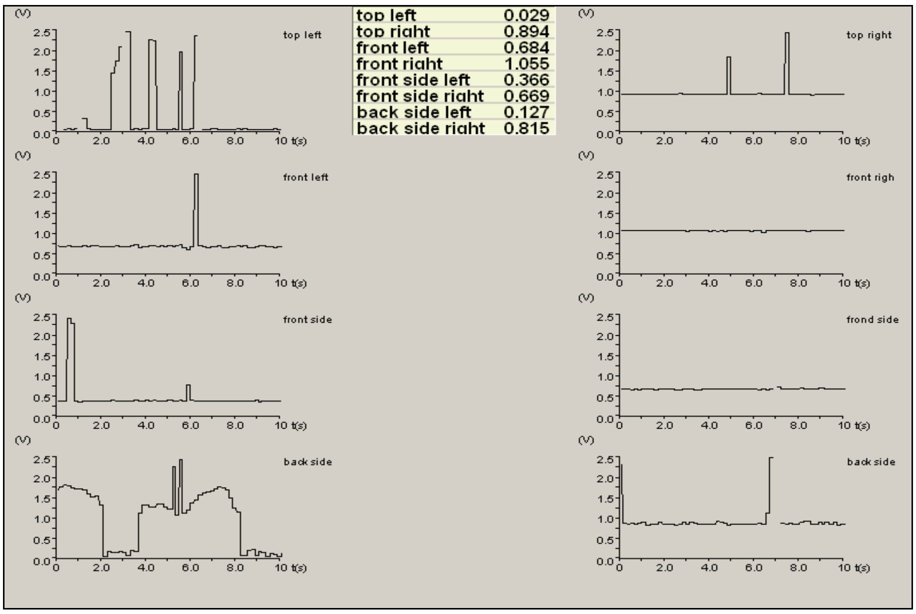


**Figure 3.2: Sensor data of the eight IR distance sensors**

## GUI von NAD

A feature of the iCONNECT software is to create graphical user interfaces in an easy way with the build in control elements. With this important parameters can be changed and process values can be displayed. On the left side of the screen the steering and sensor values are shown. On the right side is a tabbed control where algorithm settings and other parameters can be changed.

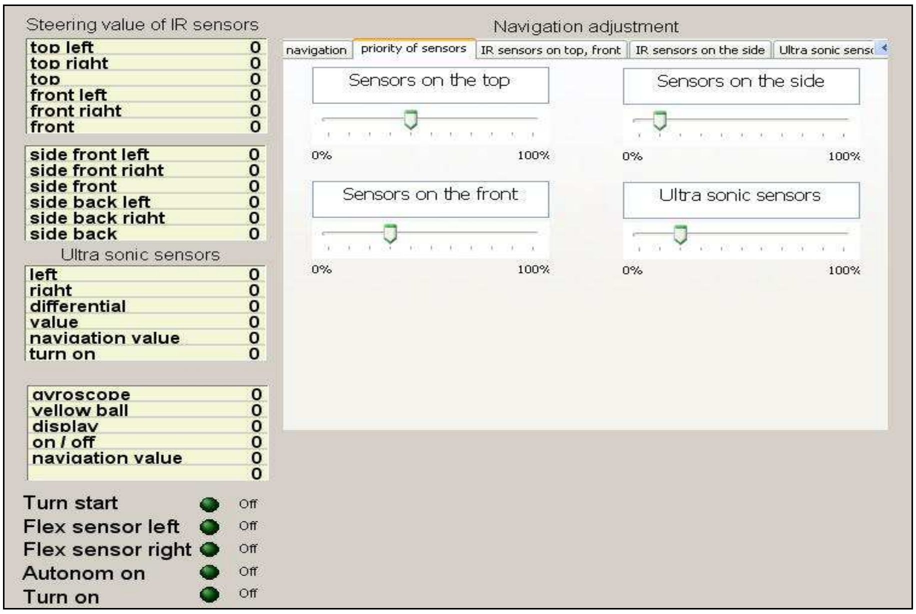


**Figure 3.3: Graphical user interfaces (GUI) of NAD**

For the navigation the row is divided into five different zones. Each of these zones stands for a predefined steering direction and strength which can be easily changed with the graphical user interface (figure 3.5). For the calculation of the position of NAD within these zones four sensor pairs are used: the two IR distance sensors mounted to the top of the robot, the two front IR distance sensors, the two side IR distance sensors and the two ultrasonic sensors.

Every pair calculates the current zone which results in a steering direction and strength this pair. Additionally each sensor pair is given a priority (figure 3.6). To calculate the final direction, the results of all the pairs are combined regarding their priority.

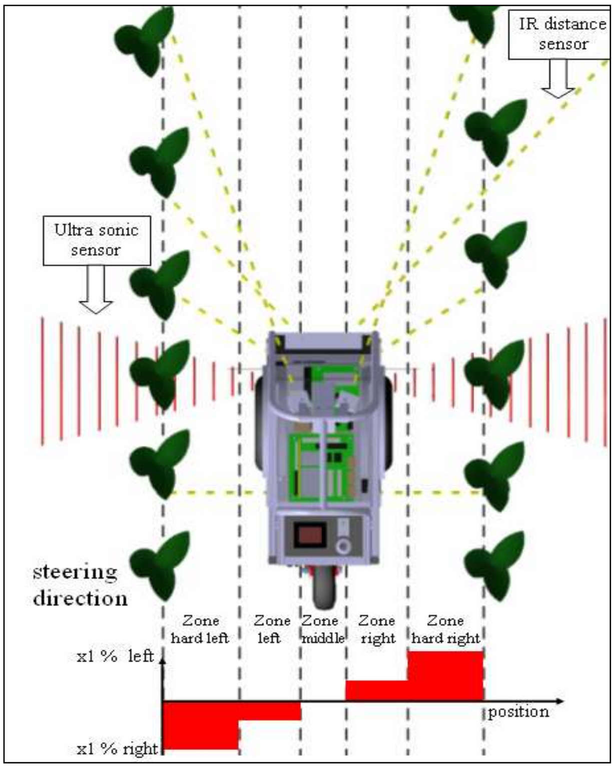


**Figure 3.4: The five zones**

Another steering decision is done by the flex sensors. They have been given an even higher priority than all other sensors, because of their ability to detect collisions with the plants. The resulting steering direction and strength can be changed in the GUI.

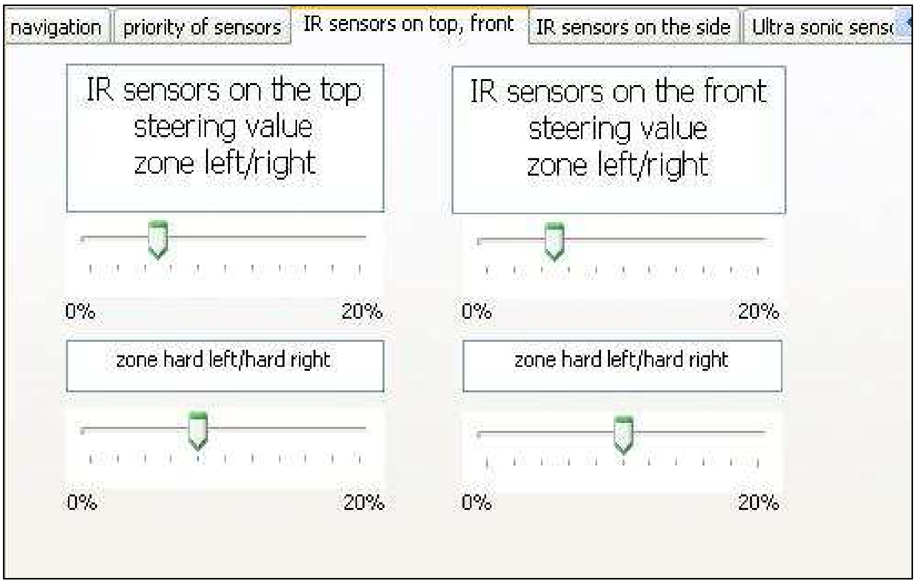


**Figure 3.5: Table steering values**

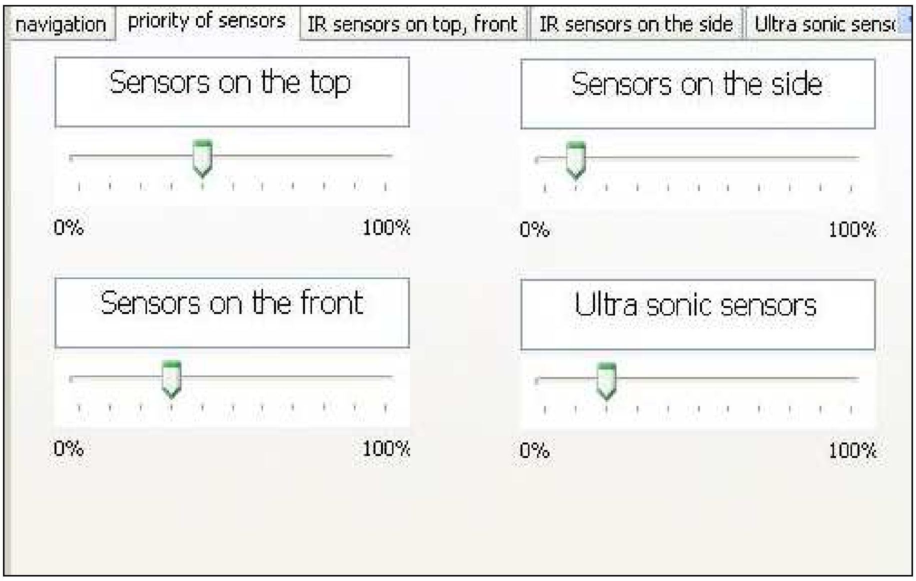


**Figure 3.6: Table priority**

# 4 Results and conclusion

At the beginning of the outdoor tests the robot had problems with the roughness of the field which has been solved by increasing the axis-center distance and optimizing the control algorithms. The navigation through the row worked very well during the contest. Another problem was the uncompleted programming of the turn at the end of the rows and the ball detection. Reasons for this are, among other things, the problems which appeared while programming with iCONNECT and its slow performance.

## References


| | |
|---|---|
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