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Development of simulation based algorithms for livestock robots

Rising costs, increasing farm sizes and constant or even decreasing working capacity open up a wide field for automation solutions, especially in the field of dairy farming. Besides established technologies such as automatic milking systems or scraper robots also automatic feeding systems become more and more important. In order to test new sensor concepts and algorithms in an early state and a cost-effective way, simulations offer a high potential. As part of a project founded by the German Federal Office for Agriculture and Food, the Institute for mobile Machines and Commerical Vehicles of the Technische Universität Braunschweig develops a new control system based on a simulation for a new generation of scraper robots and automated feeding robots in cooperation with two industrial companies and the Bavarian State Research Center for Agriculture.

Keywords
Simulation, Robot Operating System, robot, autonomous driving

Abstract
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Automatic milking systems have established themselves on the market as state-of-the-art and are used today by more than 10 000 farms all over the world [1]. Also barn cleaning is being more and more automated to reduce the human workload. A frequently performed cleaning leads to less NH_3- emissions, reduced smell and potentially improved hoof health.

In contrast to stationary barn cleaning systems, which generally use fixed traversing axes, mobile robots can also clean passages or places hard to reach. The robots follow hardcoded routes and use odometers, inertial measurement units, ultrasonic modules, transponder or touch sensors for orientation. Start and end of the route is often a battery-charging station. A front mounted dozer-blade is used to press the slurry through the slatted floors.

In the field of automatic feeding mostly stationary systems have been used so far. But also in this section the first automated mobile robot systems are available, which use odometers, ultrasonic sensors, guide wires or RFID tags for orientation, just like the barn cleaning robots. At fixed intervals the forage is loaded out of a container, mixed, and placed at the feeding fence. Additional mechanical devices at the robots' front push the forage periodically back towards the feeding fence.

To reduce the research and development expenses for future robots with its new functions, simulations can be used. The goal is to simulate new sensor concepts and control algorithms in a three dimensional virtual environment and to test their proper function. Due to external test disturbances the vehicle behaviour can be easily checked in exceptional situations.

As part of a project funded by the German Federal Office for Agriculture and Food with two industrial partners and two research institutes the TU Braunschweig has to develop a new concept for the control of a cleaning robot as well as an automated feeding robot. The vehicles shall not only move along predetermined routes, but also drive freely within defined areas in the barn or on the farmyard. For this the accurate knowledge of the robots ego position and the environment is essential. Furthermore most of the software control functions shall be used for both vehicles.

Within the project the involved companies develop new vehicle concepts or expand their existing vehicles with new functionality. The task of the Bavarian State Research Center for Agriculture is project coordination as well as checking the influence of automatic feeding systems on forage quality, the animal-technology interaction as well as the correct robot operation.

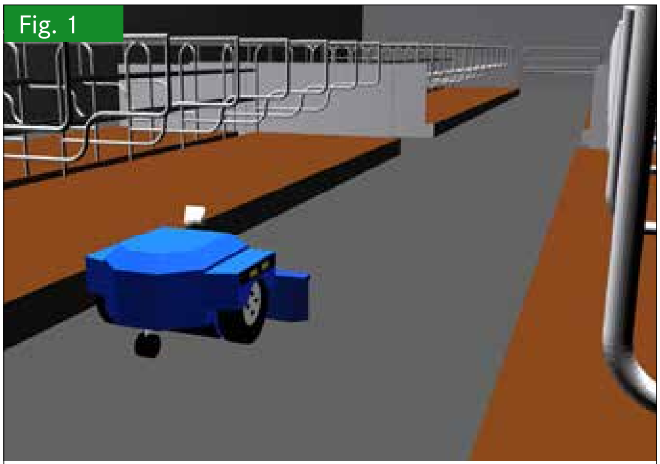
Development Environment

The Robot Operating System (ROS) has been chosen for developing the vehicle control [2]. This Linux based open-source-framework provides basic functionality for data processing, like hardware abstraction layer, various types of hardware drivers or standardised message formats. Furthermore it controls the communication between software modules, written in C/C++ or Python. This so called "nodes" can subscribe for information from other nodes, or publish information themselves. The communication protocol between the nodes is based on TCP/IP.

Due to this the information exchange between nodes is not only restricted to a single computer, but can be extended to several computers within a network or even over the internet. One advantage is that complex computing operations requiring a lot of computing power can easily be outsourced to high speed computers. Furthermore data can be checked via remote maintenance over the internet.

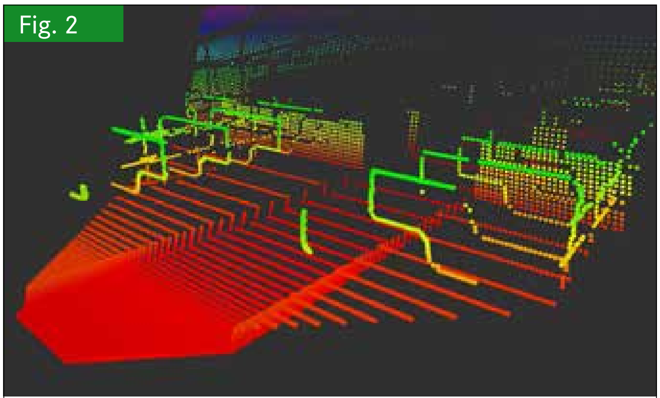
Besides ROS, an open source framework called GAZEBO is used as the simulation environment and is the second important element within the project. Virtual designed vehicles can be implemented in GAZEBO via XML data format. For this, the vehicles' structure is split up into its movable elements. Finally these elements can be parameterized with its mass, its geometrical moment of inertia, the reflectiveness of the surface, the mechanical coefficients of friction and other coefficients. Via plugins, programmed in C/C++, the vehicles can be equipped with virtual sensors and actuators. Finally the vehicles are placed within a virtual world with which they can interact. The GAZEBO simulation finally publishes information via ROS nodes, e. g. sensor information, and subscribes for information for controlling the robots' actuators leading to a closed loop simulation.

Fig. 1



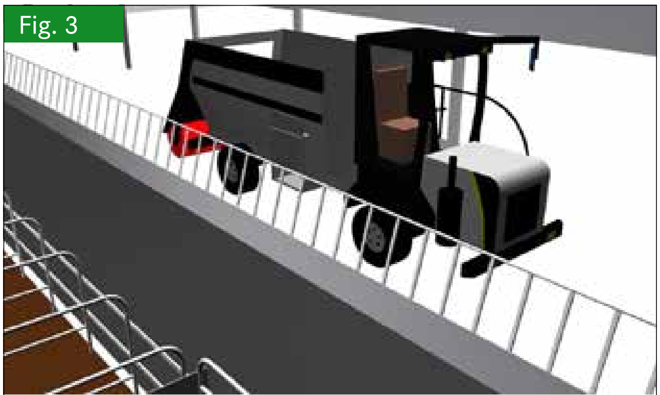
Simulation of a 3d-camera equipped mobile barn cleaner

Fig. 2



Virtual 3d-camera data

Fig. 3



Simulation of the fodder mixing wagon

Vehicle Modelling

A mobile barn cleaning robot manufactured by the company Prinzing has been build up as a simulation modell and placed in a virtual barn (**Figure 1**). Besides odometers and an inertial measurement unit the vehicle has been equipped with a time of flight camera, delivering a three dimensional picture of the robots' environment (**Figure 2**). Based on this data and an existing digital map of the barn, the robots' actual position can be estimated with the so called Monte Carlo Localization (MCL). At the beginning the robots position is unknown. The MCL tries to find all positions within the map, where the sensor data fits best to the map data. All these positions are marked with a probability of being correct. If the vehicle moves on and new sensor information arrive all non-plausible positions will be deleted, so only the position with the highest probability of being correct is left. One main advantage of this algorithm is, that even in case of power loss or other errors leading to an unknown robots position, the actual position can be estimated very quickly. A manual return of the vehicle to the start of the route is not necessary anymore. Furthermore the vehicle does not have to follow a predefined path, but can drive directly to defined positions in the barn to clean. Detecting the pressure of the dozer shield as well as using camera information it is also possible to detect those areas in the barn that become soiled quicker and need to be cleaned more often. So the system would be partially self-learning.

A modern feeding wagon manufactured by the company HIRL has also been build up in the virtual environment (**Figure 3**). Besides odometers and an inertial measurement unit a horizontally arranged 2d laserscanner mounted at the top of the cabin is used for positioning. It scans the environment, looking for reflecting stripes mounted at the inside and outside of buildings. The precise positions of these stripes are saved in a digital map. To estimate the vehicles' position the map data is compared to the measured distances and spatial arrangement of the stripes. Similar to the Monte Carlo Localization the position can be estimated.

To increase the comfort and flexibility the reflex stripe based system will be replaced later on using a self-learning system. This so called Simultaneous Localization and Mapping (SLAM) principle creates a 2d digital map based on the laserscanner data and its measured shape of the environment. In the next step the vehicles' own position within this new map is estimated. So the reflex stripes are not necessary anymore.

Conclusions

At this moment new control algorithms are tested within the simulation. Parallel the real test vehicles are constructed and equipped with sensors and computing hardware. Furthermore new mechanical functions are being implemented in the vehicles. First test trials for the algorithms and the real vehicles will start at the beginning of 2014.

References

[1] Harms, J.; Wendl, G. (2012): Automatische Melksysteme – Trends, Entwicklungen, Umsetzung. In: 39. Viehwirtschaftliche Fachtagung, 25.–26. April 2012, S. 67–74

[2] Quigley, M;. Conley, K.; Gerkey, B.; Faust, J;. Foote, T.; Leibs, J.; Wheeler R.; Ng, A. Y. (2009): ROS: an open-source Robot Operating System. In: IEEE International Conference on Robotics and Automation, Open-Source Software Workshop, IEEE, 17. Mai 2009, Kobe, Japan, http://www.willowgarage.com/papers/ros-open-source-robot-operating-system, Zugriff am 29.07.2013

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