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Convoy – safe automatical vehicle guidance based on environmental sensing technologies

Regarding to the development of automatical vehicle guidance nowadays – even in the field of agriculture – several solutions are being discussed. One solution is that one unmanned vehicle autonomously follows another manned vehicle. In agriculture parallel loading processes as well as row based tillage or seeding operations are the most common usage scenarios. In the field of automotive engineering the likely usage of this principle is in platoons or convoys of vehicles. At the Cebit 2009 trade fair a system has been presented, which demonstrates the „convoy"-mode. The system has been independently developed during a cooperation of the Götting KG and the Institute of Agricultural Engineering and Fluid Power of the TU Braunschweig.

Keywords
Vehicle guidance, safety, fuel economy, eletronical tow-bar

Abstract
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The operation of fully automated vehicles offers many advantages. In industrial environments so-called automated transport vehicles (ATV, German FTF) have been enforced for some time to deal with partially complex transport tasks. There, the vehicles are inter alia used in areas where people can stay at the same time. However, the number of serious accidents that are caused by the use of ATV (FTF) is vanishingly small.

Various operational areas of autonomous vehicles

In comparison, the usage of autonomous vehicles in outdoor scenarios generates rapidly complex and difficult challenges. On the one hand greater covered distances require higher vehicle speed. On the other hand requirements are added to the obstacle detection, the braking distance calculation as well as general security aspects in relation to other participants, such as on public roads. In addition, if the factors moisture, dust, changes of temperature or slipperiness on the roads are taken into account, the requirements for the used sensors and the data processing are rising even more. Furthermore, the ATV (FTF) is still debated for much harsher environments than road traffic, such as construction equipment and agricultural machinery.

Regardless of whether there are vehicles on roads or in off-highway environments, the autonomous vehicles can be distinguished according to the operating mode. On the one hand there is the completely autonomous operation mode of the vehicles in which the driving task must be solved completely independently. On the other hand there is the possibility of a convoy or master-slave operation, in which, for example, an autonomous vehicle follows a vehicle which is driven by a human driver.

In this article, a convoy system is described, which was presented at CeBIT 2009. The fair demonstration was completely realized by its own resources in cooperation between the Institute of Agricultural Machinery and Fluid Power of the Technische Universität Braunschweig and the company Götting KG. The project was tested and approved by the TÜV Nord on the basis of DIN EN 1525.

State of research

Convoy systems are being researched for quite some time. In the area of autonomous vehicles which are used on streets there are two major projects to emphasize. In the scope of „California PATH" (Partners for Advanced Transit and California Highway), which consists of a consortium led by the University of California at Berkley as well as many other public and private institutions, the so-called „Vehicle platooning" has been realized [1]. In Europe the CHAUFFEUR project was launched under the leadership of DaimlerChrysler. In this project trucks are coupled over an electronic tow-bar [2]. The travel data from the leading vehicle are sent to a second vehicle, which could follow the leader with this information. In both projects, a reduction of fuel consumption was sought by minimizing the distance between the vehicles. This can be realized by their sensory control. The close distance reduces the air resistance of the following vehicle, and thus its fuel consumption.

In the field of mobile equipment, especially in agricultural technology, the idea of the convoy operation is processed scientifically. Among other things there is a project worked on for two years by the chair of mobile equipment of the Karlsruhe Institute of Technology (KIT). The Federal Ministry of Research and Development funds this project, in which a tractor follows another one, according to its driving- and position signals, with a defined lateral offset [3]. In addition to the following system, there are further scenarios of cooperating driving, based on two fully autonomous field robots and their implementation through sensory hardware, tested at the Institute of Agricultural Machinery and Fluid Power in Braunschweig [4].

Fig. 1

Convoy system at Cebit 2009

Description of the convoy system

The test set-up demonstrates the basic feasibility of a convoy system using an electronic tow-bar. **Figure 1** shows the system during the demonstration at the CeBIT 2009. It consists of a tractor type Fendt Vario 818 TMS and a car type Smart. It was presented successfully under various weather conditions during the fair, even though on relatively low speeds up to 6 km/h, because of the small area.

For the safe automatic operation of the tractor the technical equipment has been added with various elements (**figure 2**). The tractor is in its basic configuration equipped with the reverse drive of the company Neumaier. In a previous work [5] at the Institute of Agricultural Machinery and Fluid Power of the Technische Universität Braunschweig a system has been developed that allows the control of the electrohydraulic steering by a separate control unit.

For driverless operation a mode is selected, where the steering wheel is mechanically decoupled. Accordingly the existing functions of the tractor for electronic steering and electronic braking can be used. The original signals of the setpoint device are simulated by a former ECU and fed into the system by a relay circuit. This ensures that the original security concept of the steer-by-wire system remains valid.

The control for the longitudinal dynamics is done directly by sending the appropriate control commands to the CAN-BUS. The tractor is operated at a constant engine speed just above idle speed; the velocity is controlled solely by the adjustment of the variable transmission. Thus the speed is limited to about 6 km/h on maximum transmission ratio.

In addition, the function of reversing, and – in case of an emergency stop – the gear neutral position can be used by direct control commands.

The current speed of the tractor is received by the corresponding CAN message from the gear bus. Furthermore the information of a second velocity signal, generated by an encoder installed in the rear wheel, and a steering angle sensor installed on the front axle are captured and processed in the central ECU. The deceleration of the vehicle is primarily achieved through a transmission change of the variable transmission. Furthermore the brake-by-wire system, which is active in the above-described operating mode is used and controlled by an analog signal.

For a safe emergency stop in the low speed range, the tractor integrated air brake system is used. An additional safety electromagnetic valve is integrated as a bypass into the line connected to the hand brake function (**figure 2**). This will open in an emergency case or in case of power loss, which leads to a response of the service brake. Simultaneously the clutch is opened to disconnect the drive from the engine synchronously to the emergency brake.

In the front three-point suspension of the tractor a construction is installed, in which several detection and security functions are housed, which are described in the following section.

Comprehensive security concept

The security concept consists of multiple, independently operating systems. A laser scanner (type LMS 291) is used only for object detection. A further, for outdoor use approved safety laser scanner (type LMS 221) is also installed in the front linkage and controls a defined area of security to foreign objects. To check the functioning of the scanner there is a permanently installed reference object, which must always be detected (**figure 3**). If additional objects appear in the defined security zone of 1.5 m in front of the tractor or if the reference target cannot be detected, a signal line is activated.

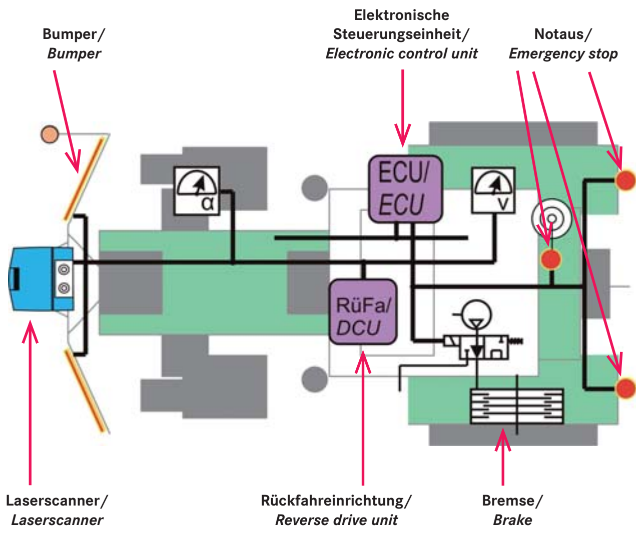
There are further additional guards, three sensitive edges installed at the front bar, so-called bumpers, two emergency stop buttons on the rear fenders of the tractor, a radio emergency stop in the control unit of the car and an additional radio emergency stop in a mobile hand-held unit. If one of these systems is set in motion, a defined emergency stop of the vehicle is started. All signals are evaluated by a central security control unit type UE4470 of the company Sick. In an emergency, the above-described quick exhaust in the bypass of the air brake switches and the tractor is quickly brought to a standstill.

Several scenarios

The aim of the cooperation was to build a demonstration system in which two vehicles should drive in the convoy operation. In addition to the convoy scenario (**figure 4** left), in which the unmanned vehicle follows a preceding vehicle with driver, also a modus to drive parallel to each other was developed (**figure 4** right). In this mode the motion of the car is recognized through corresponding installed sensors and transmitted to the tractor. Furthermore, the tractor can be controlled by a remote control. The processing of the information is also done by the aforementioned ECU.

In the convoy scenario the vehicle in front of the tractor is recognized by a laser scanner installed in the front linkage (Sick LMS 291). To ensure the unambiguous assignment additional markers are installed at the rear of the car. For the path planning further information are also included, like the speed of the vehicle ahead, the geometric dimensions and parameters of the potential of driving, braking and acceleration. Using the parallel driving mode also the above mentioned information are transferred between the vehicles. Taking the different vehicle geometry into account the handling of the car is modelled through the tractor. Different parameters allow adjusting the offset in the longitudinal and transverse directions. The security concept is also active using the parallel driving mode and allows the described emergency stop, if an object appears in the area in front of the tractor. The data transfer between the car and the tractor is realized via a radio interface on 433 MHz base.

Fig. 2



Technical setup of the leaded tractor

Conclusions

The Götting KG and the Institute of Agricultural Machinery and Fluid Power at the TU Braunschweig showed with an in direct cooperation built model (a convoy demonstrator) with which kind of construction an electronic tow-bar can be functionally operated under safety conditions (reliability, „fail-safe-mode"). In addition to the listed similar works, in which the absolute position (GPS) of the vehicles is used, in this work a more extensive aspect was handled: driving with sensitive reacting on the surroundings. The results of the project are currently used by both partners in research and development activities in the area of coordinated and cooperative driving.

Literature

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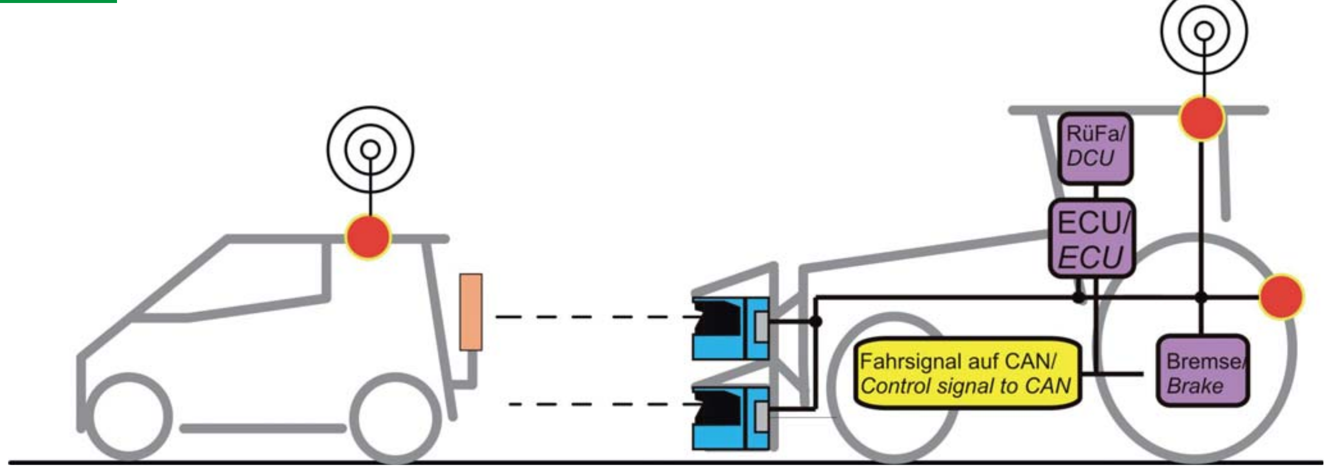
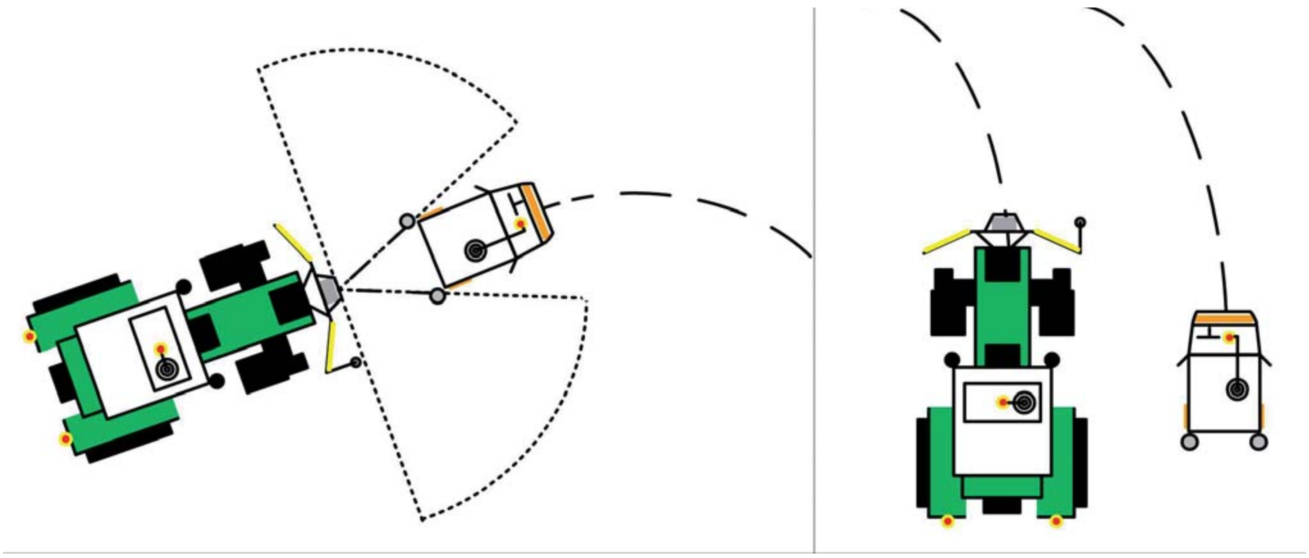
Fig. 3



Safety concept during convoi-driving

Fig. 4



Left convoy-mode, right paralleldriving-mode

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