Dipl.-Ing. Thorsten Lüttel
Universität der Bundeswehr München,
Institut für Technik Autonomer Systeme

thorsten.luettel@unibw.de

Dipl.-Ing. (FH) Michael Manz
Universität der Bundeswehr München,
Institut für Technik Autonomer Systeme

michael.manz@unibw.de

Vehicle Tracking for Unmanned Vehicle Convoys

Unmanned ground vehicles (UGV) can reduce threats and cognitive loads of soldiers during a mission considerably, e. g. when operating autonomously to perform transport or reconnaissance tasks. In a current research project, the University of the Federal Armed Forces Munich is working on the subject of autonomous vehicle convoys, especially on a continuous and robust tracking of a leading vehicle, using sensor data from an onboard camera and light detection and ranging (LIDAR) sensors.

Integration of autonomous functions into a UGV has many advantages over pure radio-control, which in turn is affected by radio reception dead spots and high operator cognitive load. At present, autonomous vehicle convoys are one of the more likely scenarios for the use of UGV in the military. Algorithms and techniques for this purpose have been developed at the University of the Federal Armed Forces Munich. The implementation has been presented on their demonstrator vehicle MuCAR-3 (see Figure 1).

The basis for an autonomous UGV in a convoy is a very robust and continuous perception of a specific leading vehicle. The method developed to detect the leading vehicle is either based on data from a LIDAR system (Velodyne HDL-64E) or images from a colour camera, or on a combination of both. A powerful on-board computer estimates the relative position of the leading vehicle compared to the UGV in real time, independent of GPS information or radio-linked data from a base station or the leading vehicle. For robust perception in a complex environment, the position in all six degrees of freedom (spatial and angular position in space) is estimated. In addition,

Fig. 1: **MuCAR-3 (Munich Cognitive Autonomous Robot Car, 3rd Generation) during the "Transport-Movement" scenario at the M-ELROB (Military Land Robot Trial) 2010**

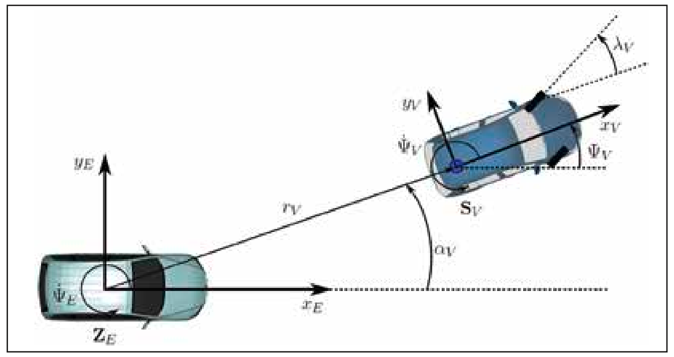

Fig. 2: **Position of the leading vehicle in an egocentric cylindrical coordinate system**

Univ.-Prof. Dr.-Ing. Hans-Joachim Wünsche
Universität der Bundeswehr München,
Institut für Technik Autonomer Systeme

joe.wuensche@unibw.de

the estimation of velocity and steering angle of the leading vehicle enables the temporal prediction of its movement (see Figure 2).

The basis for this algorithm is the so-called 4D approach utilising spatio-temporal models of the leading vehicle and the UGV. A 3D CAD model consisting of corners, edges and surfaces is utilised to describe the shape and appearance of the leading vehicle in the sensor data (see Figure 3). This CAD model and the model of vehicle dynamics, together with the estimated vehicle states, form the internal model representation of the environment at a certain point in time.

Possible positions of the leading vehicle are generated in 3D space for the next point in time, based on the current model representation, and then projected into the sensor data (e. g. the colour image). These hypotheses are evaluated on the basis of learned colour and gradient signatures (e. g. light-dark transitions around the windows) and obstacle signatures of the leading vehicle in the camera image, and of its appearance in the LIDAR data. The best-rated hypotheses are used to estimate the leading vehicle's position and dynamics, and to update the internal spatio-temporal models.

By sensing the UGV's surroundings with camera and LIDAR sensors, the presented system is able to robustly follow the leading vehicle through unstructured terrain even in challenging situations, such as partially obscured leading vehicle, heavy rain or complex light conditions such as low sun.

Moreover, the UGV follows precisely in the track of the leading vehicle and doesn't cut sharp corners (see Figure 4). In the tests with MuCAR-3 speeds of up to 80 km/h were obtained, limited by the sensing range.

Using the presented system, robust unmanned driving in convoy is possible both on and off roads. At M-ELROB 2010 (Military European Land Robot Trial), the system was demonstrated successfully on all levels of difficulty. Current work at the University of the Federal Armed Forces Munich is focussed on three aspects: first, expansion of the capabilities, second, higher sensor and operational robustness especially for more mission-like scenarios including convoys composed of several vehicles and driving at greater distances between them, and third an implementation of the system to a Rheinmetall MAN Military Vehicles (RMMV) HX58 type military truck.

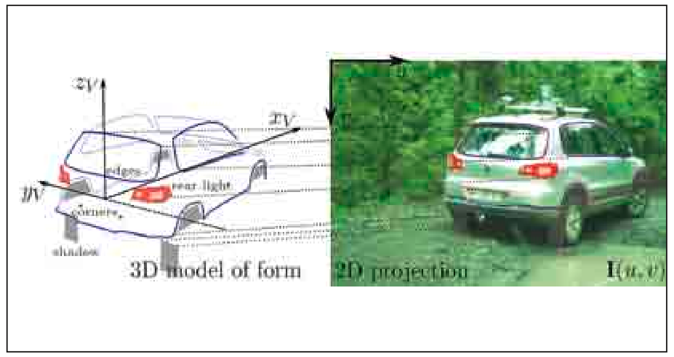

Fig. 3: **All characteristic features of the 3D CAD model are projected into the 2D image plane**

Fig. 4: **In the left part, the path is shown which the UGV has to follow. Green circles represent local waypoints and their probabilistic uncertainty. Additionally, obstacle information (red dots) are shown superimposed on a georeferenced aerial image. The right part shows the colour camera image with an overlay of the estimated model position**