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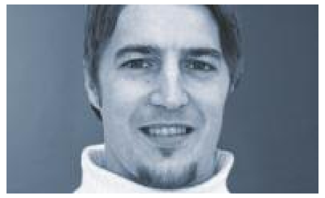

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Visual Perception and Autonomous Navigation for Unmanned Ground Vehicles

Autonomous ground vehicles offer the possibility to highly reduce threats and cognitive loads of soldiers during a mission. For this the robot, like a human driver, has to perceive the environment. Visual perception has the advantage of being passive and less prone to detection, while being technically very challenging, however. Robust visual perception of navigated routes is a first important step for autonomous navigation.

Remote-controlled systems are receiving ever more frequent consideration as means of increasing the distance between military personnel and potentially hazardous areas. Remote control alone, however, has several disadvantages. Not only is the operational range of the system heavily restricted by the range limits of the video and / or control communication link, but also the cognitive burden on the teleoperator is very high. Autonomous sub-functions integrated into the robot are a means to solve this dilemma. Hence a research project by the Bundeswehr Technical Centre for Information Technology and Electronics (WTD 81) is focusing on autonomous navigation on minor roads in unstructured terrain.

The University of the Federal Armed Forces in Munich can draw upon a wealth of experience in this field. For over 25 years, the Institute for Autonomous Systems Technology has been developing autonomous mobile robot platforms. A modified VW Touareg – the Munich Cognitive Autonomous Robot Car 3rd Generation (MuCAR-3) – equipped with computer-controlled actuators and sensors is available as the latest demonstrator platform. Using algorithms developed

Fig. 1: **Munich Cognitive Autonomous Robot Car 3rd Generation (MuCAR-3), the third-generation experimental vehicle of the University of the Federal Armed Forced Munich**

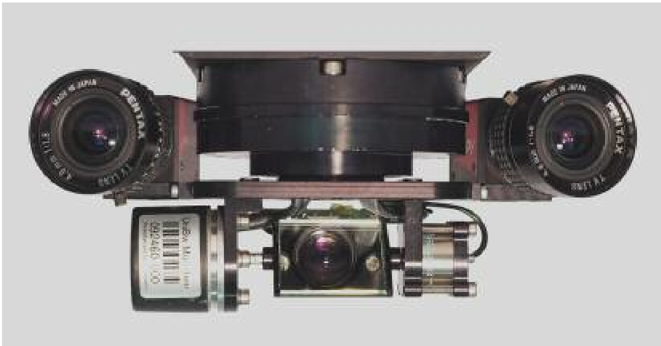

Fig. 2: **MarVEye8: a camera platform with human eye-like characteristics (large field of view, focal vision with high resolution, image stabilization and fast saccadic movements)**

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in this research project, MuCAR-3 is able to navigate autonomously along road / track networks both in open and wooded terrain. Depending on the quality of its visual road / track recognition and accuracy of the GPS / IMU system it switches dynamically between visual and map-based navigation, and is thus able to cover also large distances fully autonomously.

Its main sensor for visual road / track recognition is the camera platform MarVEye8 (Multifocal active / reactive Vehicle Eye, 8th Generation), equipped with three CMOS-HDRC colour cameras. The platform can look into turns thus keeping the road in the center of the view while allowing inertial pitch axis view stabilization. A high performance computer system onboard MuCAR-3 permits real-time visual road / track detection.

The algorithm developed for road / track recognition is based on the latest research work at the Institute for Autonomous Systems Technology. The core of the algorithm is the so-called 4D approach, comprising spatio-temporal modelling of the road or track and of the vehicle's ego motion. Using internal models of the environment, 3D hypothesis of possible road / track shapes and locations are generated and projected into the video image using the perspective mapping properties of the actual colour cameras used. These road / track hypotheses are then evaluated on the basis of online-learned road / track colour and gradient signatures of their images.

These techniques enable MuCAR-3 to drive autonomously along asphalted roads as well as forest- and dirt tracks even without any GPS-information. The image processing system responds robustly to any visual disturbances such as shadows, varying camera exposure or visual clutter along the path.

Several of the approaches developed in the research project have already been demonstrated successfully at M-ELROB 2008 (Military European Land Robot Trial), C-ELROB 2009 (Civilian ELROB) and M-ELROB 2010. At last year's ELROB 2009 in Finland, MuCAR-3 was even able to negotiate a difficult circuit several kilometers in length in woodlands finishing fastest.

Further research projects at the Institute for Autonomous Systems Technology are focusing on very high-performance image processing methods for visual object recognition, stereo image processing for humanoid robots, Light Detection and Ranging (LIDAR)-based environment perception and navigation, as well as novel object-oriented navigation and mission planning methods.

Fig. 3: **Visually recognised dirt road in unstructured terrain and indication of the recognition quality**

Fig. 4: **Map-based mission planning in a test area**