Testing Intelligent Road Vehicles

- TNO Automotive building large test facility VEHIL
- Control systems for automatic guided vehicles
- Controller prototyping with dSPACE AutoBox

To facilitate the development and testing of intelligent transport systems, TNO Automotive has developed an intelligent vehicle test facility called VEHIL (**ve**hicle **h**ardware-**i**n-the-**l**oop). VEHIL consists of a test vehicle, wheeled robots (moving bases) representing other road users and an experiment controller. Because of good experience gained in previous projects, TNO decided to use dSPACE Prototyper in this project too. The computational hardware for controller prototyping of the moving bases was realized using AutoBox.

Modern society's ever-increasing desire for greater mobility is placing an enormous demand on the expansion of existing transport systems for both people and goods. However, this expansion is being severely curbed by the limited space available and the constraints imposed by environmental legislation. One of the solutions is to enhance the efficiency, capacity and safety of today's road network by developing intelligent transport systems. With our intelligent vehicle test facility VEHIL, these new systems can be tested thoroughly in a laboratory environment, i.e., more safely, cheaply and manageably than on public roads.

VEHIL Concept: Full-Scale Testing Under Laboratory Conditions

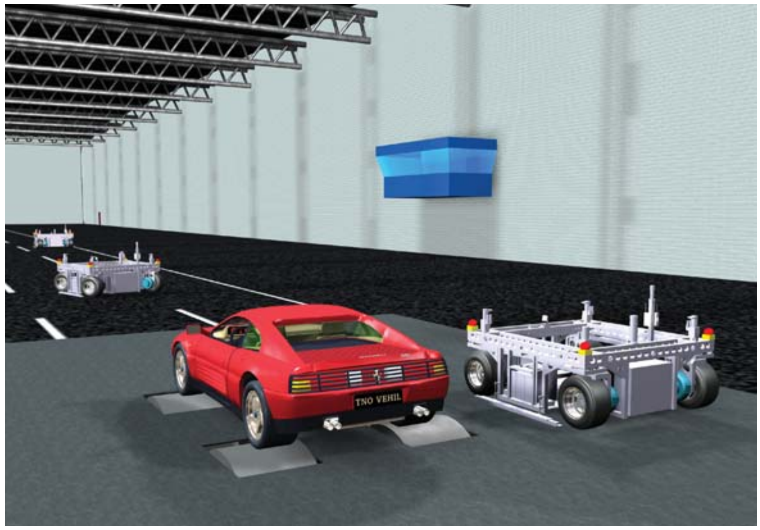
To evaluate the functionality of an intelligent vehicle, its sensors and actuators have to be subjected to realistic driving conditions, such as high vehicle speeds and realistic tracking distances. This usually involves expensive and risky road tests. TNO has developed an alternative in which a vehicle can be tested under laboratory conditions, while realistic road conditions are being simulated. In VEHIL, the complete intelligent vehicle is placed on a chassis dynamometer. The vehicle is able to ride and brake as if on the road. The dynamometer simulates road behavior based on a simulation model of the test vehicle. Realistic vertical movements caused by braking and accelerating are ensured through the use of an advanced vehicle fixation system. The maximum speed is 250 km/h. Realistic emergency braking can be simulated up to 150 km/h for most vehicles. The chassis dynamometer can accommodate very small vehicles as well as small trucks and busses up to a mass of 12,000 kg.

▶ *Dehlia Willemsen and her colleagues with the moving base.*

The Moving Bases

Other road users in VEHIL are represented by automatic guided vehicles, the so-called moving bases (MBs). To execute the complex maneuvers that arise from the relative movements of the test vehicle with respect to neighboring vehicles , the MB must be able to maneuver unhindered in all directions. This resulted in a unique package of requirements which was the reason to develop and build this MB in-house and trust in the capabilities of dSPACE's AutoBox, which we knew from former projects.

A lightweight (plastic) representation of a car body can be attached to the MB chassis, completing the resemblance to a normal

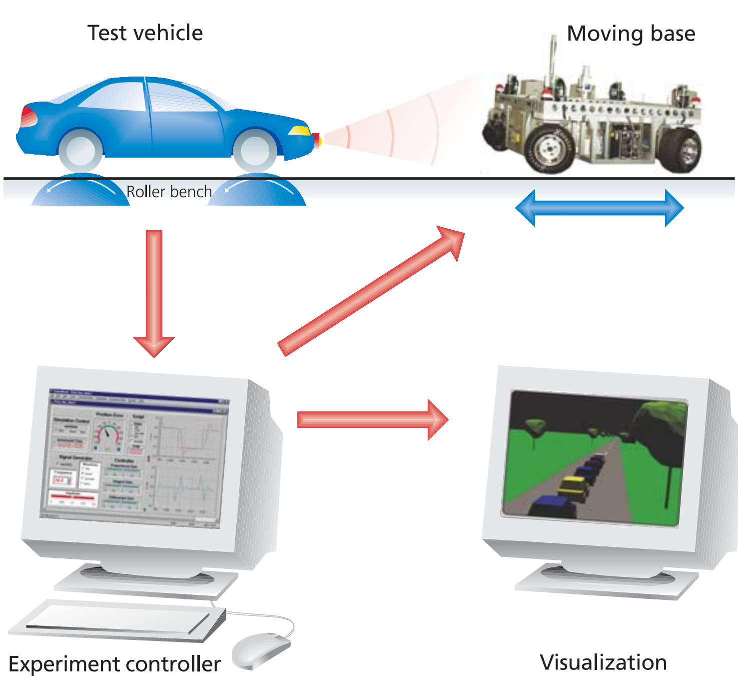


▲ *The vehicle test facility (VEHIL) with the test car and other "road users", the moving bases.*

vehicle in traffic. The MB has a four-wheel drive and steering concept, hence it is possible to control the vehicle's three directions of movement (longitudinal, lateral and yaw) independently of one another. In addition, the MB can accelerate and brake with a maximum of 1 g in all directions. This is important for simulating an emergency stop of the test vehicle.

Moving Base Controller

The control system of the MB consists of two main hierarchical levels. The higher level is the path-following controller. It uses measured signals indicating the actual position and orientation and compares these to the reference trajectory sent by the VEHIL experiment controller. Based on this comparison, eight actuator signals are calculated using the concept of a virtual actuator that acts on the center of gravity of the MB, which is the lower-level controller. Using the virtual actuator, a decoupled motion control system is achieved for the overactuated MB (eight actuators for three degrees of freedom). Hence the higher-level path controller simply consists of three independent control loops: the longitudinal, the lateral and the yaw control loop. The controller runs on dSPACE's AutoBox with the DS1005 PPC board as the processor board and five different I/O boards. Eight actuators and numerous sensors (incremental encoders, accelerometers, gyroscopes, position measuring systems, etc.) are used for control. dSPACE's experiment software ControlDesk controls, monitors and visualizes the test variables. The MB can also be controlled manually via remote control using the same lower-level controller and hardware.



◀ *The VEHIL principle of operation.*

Two MBs have been built and are undergoing final testing with the prototype controller, using ControlDesk in combination with MATLAB®/Simulink®. The VEHIL test facility was officially opened November 2003 with large national and international interest. VEHIL is now welcoming its first customers.

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