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Towards Unmanned Autonomous Road Vehicles Through Building of Intelligent Control System Based on a Cognitive Driver Model

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The paper is of a conceptual character. It is addressed to building of novel intelligent active safety and emergency warning systems operating with road vehicles based on a cognitive-motor, psychological and physiological model of human operator. Building of unmanned autonomous vehicles is a challenging task that can be potentially interesting for military applications especially for the future robotized combative vehicles and autonomous transporters. Modelling of hybrid, driver-vehicle system represents the basis (core) for synthesis of an intelligent, driver-assisted control system considered in the paper. Modelling of the system takes into account a spatial, non-linear vehicle dynamics and tyre-road interaction as well as characteristics of the psychological and the physiological behaviour of a human operator. Two variants of safety systems are presented in the paper: (i) emergency warning system dedicated to warn about approaching of an emergency situation, and (ii) automatic, active-safety control system capable to guide vehicle in an autonomous regime. Corresponding, contemporary hi-tech servo-actuators and a sensory system capable to support the proposed safety system are presented, too. Some characteristic simulation results/examples are provided to demonstrate system capabilities and verify control performances. The paper ends with summary comments and conclusions.

Key words: **unmanned vehicle, road vehicle, wheeled vehicle, vehicle control, control system, hybrid system, safety system, system modeling, test results.**

Introduction

THE justified reason for high vehicle automation, apart from higher controllability, safety and ride quality, is in the permanent vehicle designer's tendency to substitute the human factor by an automatic control system as much as possible since it is an element with limited control capabilities. Contemporary road vehicles possess different active control systems such as: active suspension system, anti-blocking system ABS, four wheel steering (4WS), traction control (TRC), four wheel driving (4WD) and braking (4WB), ESP electronic stability system, etc. Using driver assisted systems, the control system acts as a corrective factor to the manual commands of a human operator (Fig.1).

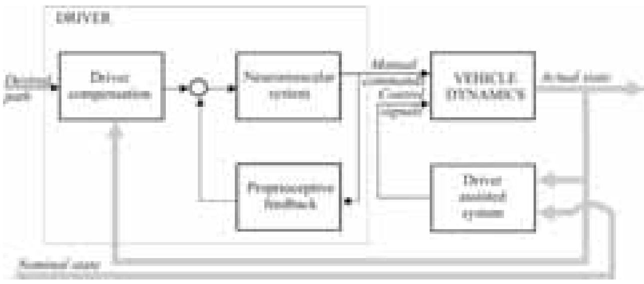

Figure 1. Block-scheme of the driver-vehicle system with a driver-assisted control system in the loop

Interactive control of vehicle dynamics as well as problems of active safety have been predominantly considered during the last two decades in three possible ways: (i) by synthesis of control methods based on implementation of 4WS, (ii) applying Direct Yaw Moment (DYM) control by use of 4WD and 4WB system or TRC system, and (iii) using integrated control combining 4WS and independent 4WD/4WB, implementing DYM control algorithms. In that sense, within last few years several car manufacturers developed car prototypes equipped with non-conventional steering systems based on a 4WS configuration [1] and [2], etc. The additional degree of freedom offered by rear wheels steering could be exploited to improve vehicle dynamics by means of suitable automatic controllers, while leaving the primary function of path tracking to the human driver. Such improvements include better manoeuvrability at low speed, stability augmentation at high speed, reduction in sideslip angle and rejection of lateral force disturbances. However, vehicle lateral dynamics is dramatically changed with a friction coefficient between the tire and road surface. Tire force condition strongly affects the control system performances. DYM control systems using driving/braking forces have been researched and developed [3] also to improve handling and stability. One of them is an active TRC system of each wheel through the feedback of state variables, such as the yaw rate. The other is an active braking control system through the feedback of state variables, such as the yaw rate and/or the sideslip angle of the vehicle body. These active control systems can generate the yaw moment directly to compensate for vehicle yaw motion not only in the linear ranges (as 4WS systems), but also in non-linear ranges of tire performances. In that way they compensate for the drawbacks of the 4WS during saturation of tire lateral forces.

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Besides pure longitudinal slip control systems, the newest technology considers both longitudinal and lateral slip angles. These Dynamic Driving Control systems (DDC) monitor also lateral dynamic driving behaviour. In contrast to longitudinal slip control systems, brake and engine management intervention may happen [4] without the driver's activity. DDC supports the driver in critical driving situations.

The design of most existing control schemes relies on the popular "single track" linear model of the vehicle dynamics [5]. This 2-DOFs linear model is suitable for design of various types of the robust controllers (H_∞ , μ -synthesis) [6], but it neglects some important aspects of the interaction between tires and road surface. The phenomena like roll and pitch dynamics, vertical heave motion of vehicle structure and a sophisticated description of the nonlinear tire characteristics have to be included into consideration for the control design, especially for the high-speed vehicle manoeuvres. For the purpose of simulation of complex vehicle dynamics in different driving conditions a spatial model [7] is used. For the purpose of synthesis of an active safety system considered in this paper, a cognitive driver model [8] is considered, too. Both models are briefly described in the next section.

Modeling of Hybrid Driver–Vehicle System

Modelling of hybrid driver-vehicle system represents a platform for designing intelligent, active-safety control structures considered in the paper.

Modelling of Vehicle Dynamics

A spatial, non-linear dynamic model of a road vehicle with 22 degrees of freedom in mechanical sense [8], including the non-linear tire model, is assumed as appropriate for system studying, control synthesis and simulation. This model describes entire vehicle dynamics, i.e. main physical phenomena in the system in a satisfactory good way. The phenomena like lateral and yaw dynamics (during high speed manoeuvres), roll and pitch dynamics, vertical (heave) motion of the vehicle body and sophisticated description of the non-linear tire characteristics are included in this model. The vector relation describing this model can be expressed in the form:

$$H(\underline{q},d)\,\ddot{\underline{q}} + h(\underline{q},\dot{\underline{q}},d) = \tau + F(\underline{q},\dot{\underline{q}},d) \tag{1}$$

In relation (1) the following notification was used: $\underline{q}$ represents a (6×1) vector of system state variables describing position/orientation of the vehicle body mass centre (MC) with respect to the coordinate frame fixed to the ground. The state vector has the following elements:

$$\underline{q} = [x \quad y \quad \varepsilon \quad z \quad \phi \quad \theta]^T \tag{2}$$

The coordinates x , y and z represent the longitudinal, lateral, and vertical positions of the vehicle MC along the three coordinate directions, expressed in $[m]$; ϕ , θ , ε are the corresponding angles of roll, pitch and yaw of the vehicle body in $[\text{rad}]$; $H(\underline{q},d)$ is a (6×6) inertia matrix expressed in $[\text{kg}]$ or $[\text{kg}\,\text{m}^2]$; $h(\underline{q},\dot{\underline{q}},d)$ is a (6×1) vector of gravitational and centrifugal forces/moments acting at the vehicle MC, expressed in $[\text{N}]$ or $[\text{Nm}]$; τ is a (6×1) vector of driving forces and torques referred to the vehicle MC produced by tire forces, also in [N] or [Nm]; $F(\underline{q},\dot{\underline{q}},d)$ is a (6×1) vector of the external forces and torques effect on the vehicle body during its motion. The elements of this vector take into account forces and torques of tire rolling resistance, aerodynamic resistance forces during motion, and damping torque of yaw rate during cornering. The vector d represents a (l×1) vector of the system parameters. As a model of tire pneumatics, known as "The Magic formula", a tire model [9] was assumed to describe the non-linear nature of tire dynamics with a desired accuracy.

For the purpose of control design as well as for modelling the driver's behaviour, the following kinematic variables should be determined. Having in mind the fact that the longitudinal, lateral and yaw vehicle dynamics are strongly coupled and mutually interconnected, the orientation angle ψ of the vehicle speed vector can be calculated in the following way:

$$\psi = \arctan\left(\frac{\dot{y}}{\dot{x}}\right) \tag{3}$$

where $\dot{x}$ and $\dot{y}$ are speed values of the road vehicle in the longitudinal and the lateral direction of motion. Then, the so called side slip angle of the vehicle body can be defined in the following way:

$$\beta = \psi - \varepsilon \tag{4}$$

In (4) ε is the yaw angle of a road vehicle during motion. The variables ε , ψ and β are important kinematical variables used for the modelling and calculation of control signals.

Modelling of Driver Behaviour

Modelling of the cognitive-motor driver behaviour gives new perspectives for synthesis of advanced intelligent driver-assisted, safety-stability control systems. In this paper three functions of the driver behaviour are modelled:

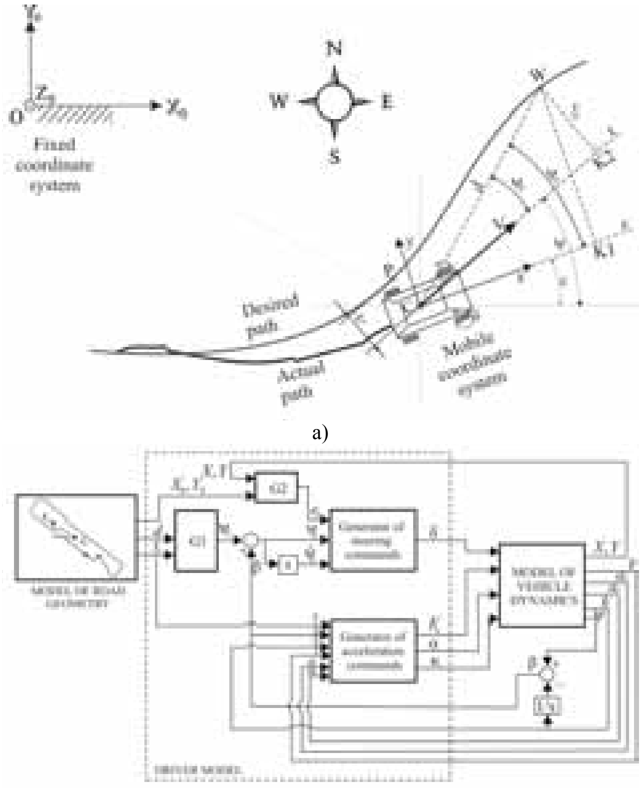
(i) adaptation to the road geometry conditions, i.e. trajectory tracking mode,
(ii) obstacle avoidance and collision avoidance, and
(iii) platooning, i.e. moving in convoy (leader-follower regime).

Generally spoken, a driver is able to access proprioceptive information from the motion of human limbs and muscle tissue as well as from his/her vision. Taking in mind this fact, the closed-loop structure of the driver-vehicle system represents a *multi-input – multi-output* (MIMO) system [10]-[11]. The model uses as input the following variables: (i) the current speed, (ii) side error of vehicle lateral position, (iii) longitudinal and lateral acceleration, (iv) yaw rate, (v) side slip angle of vehicle body, etc. (Figures 2a and 2b).

In Fig.2b a block scheme of the MIMO driver model is shown. The driver model is required to include three essential components [10]. The first of these components represents a time lag which consists of dead time resulting from information processing in the central nervous system and delay due to the dynamics of the muscular system including the man-machine interface dynamics (steering wheel, acceleration pedal, braking pedal). It can be assumed that the mentioned lags are not subjected to any changes due to the driver's intention. The second component of the model represents the lead or the predictive action of the driver. It means that the driver controls the vehicle by predicting future values of target signals. The last components of the driver's model are the corresponding gains representing the driver's proportional action [10] to the road geometry.

In order to realise desired driver-vehicle system characteristics, the driver adjusts the values of his or her own gains and lead time characteristics according to the vehicle characteristics and the assigned task (driving manoeuvre). In this paper a novel, non-linear, fuzzy model was derived. The input and the output variables of the proposed driver model are graphically presented in Fig.2a. This model is valid for any driving situation and road geometry. It was adopted for closed loop simulation as well as for synthesis of an intelligent safety-stability control system. The parameters of the model are tuned experimentally.

The MIMO model of the vehicle human operator presented in Fig.2b has two main modules: (i) generator of the steering commands δ and (ii) generator of the acceleration/braking commands (throttle position α, braking force F_b and traction/braking indicator κ). The steering problem concerns the way of determining the steering wheel angle based on perception of the desired road geometry and the actual state of road vehicle (current position on the road, forward speed, yaw angle, side slip angle, etc.). The blocks G1 and G2 in Fig.2b represent the trigonometrically functions as well as the relations of analytic geometry. The outputs of these blocks are led to the blocks for generating commands. The differentiator and the integrator of the signals in Fig.1b are represented by the blocks s and 1/s where s is the Laplace operator.



a)

b)

Figure 2. a) Characteristic variables describing the model of road geometry used as the input arguments of the cognitive driver model, b) Block diagram of the multi-input - multi-output driver model

The steering problem is determined by the driver's perception of the "forthcoming" road geometry. In that sense, the Preview point (the point W in Fig.2a) is of essential interest for the road geometry detection. The predictive characteristics of the driver model proposed in this paper are related to the position of this point. The driver as a vehicle operator leads car to track the hodograph of displacements of the Preview point W by changing the steering wheel angle. The distance of the Preview point is variable. It depends on the actual forward velocity of the road vehicle.

Concerning modeling of obstacle avoidance and collision avoidance as well as modeling of vehicle maneuvers, the following variables are of interest presented in Fig.3. The driver, according to the cognitive capabilities, estimates the necessary acceleration and speed as well as corresponding steering maneuvers to avoid fixed or mobile obstacles.

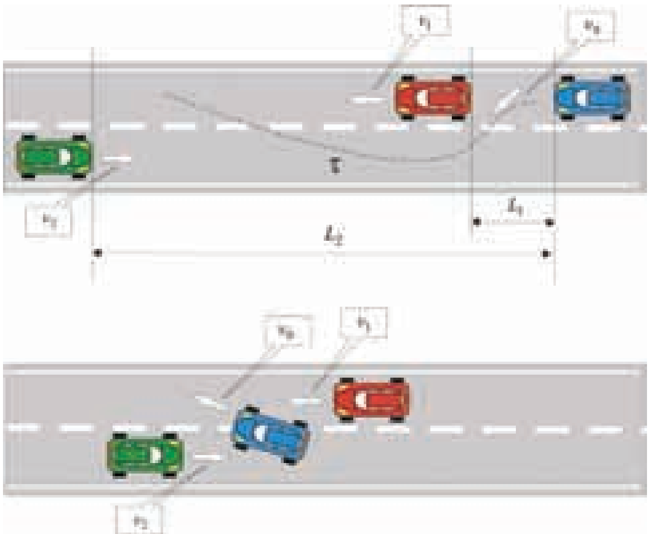


Figure 3. a) Characteristic variables describing model of a collision avoidance used as arguments of the cognitive driver model

For modelling of flocking (platooning) of road vehicles, the speeds of the leader and the follower are of importance as well as the safe distance. The safe distance between vehicles moving in column is variable depending on the actual tracking speed and time lag as a parameter of the driver model. This parameter is adjustable depending on driver skills, age and psychological conditions (sleepiness, sickness, etc.).

The driver model, considered in this paper, represents a rather complex knowledge-based or case-based control structure consisting of a set of rules and corresponding weighting functions which describe driver perceptive-cognitive and motor capabilities.

Active Safety Systems based on the Cognitive Driver Model

The previously described cognitive-motor driver model represents the core for development of different active-safety, hi-tech driver-assisted systems and corresponding interface for measurement of driver cognitive effort.

Mesurement of driver cognitive effort and manual driving skill is of high importance, especially in a training phase of new/young drivers. The concept of the system for measuring driver skills is presented in Fig.4. The system operates in such a way that compares driver's manual commands (obtained from the vehicle command devices) with the corresponding referent command variables calculated by corresponding DVL+ software interface (Fig.4). DVL+ software interface represents a cognitive-motor driver model identified for the case of a high trained experineced vehicle operator (driver instructor). By a simple comparison of the actual driver commands (measured at the driver-vehicle command interface) and the commands generated by an DVL+ interface, the level of driver operational skill can be estimated/assessed with satisfactory accuracy. DVL+ software interface, for its operation, uses signals from a GPS receiver (about actual position on the digital map and about road geometry) as well as a telematic system. A telematic system serves to identify obstacles on the road as well as to enable estimation of a relative speeed of the vehicle with respect to the obstacles in surrounding. In such a way, the system presented in Fig.4 represents an auxiliary safety system that helps inexperienced drivers to improve their skill through the process of training as well as in the early phase of their driving practise.

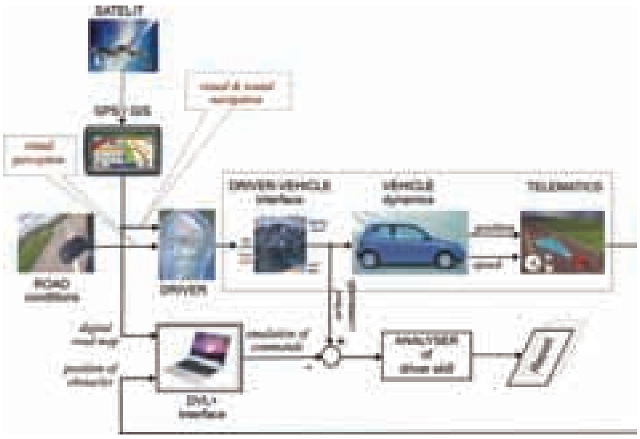


Figure 4. System specialized for the measurement of cognitive driver effort during motion

Another system, derived from the driver model, represents an emergency risk warning system to be used on-board in the car. The system is presented in Fig.5. It operates in a similar way as a system presented in Fig.4 with a difference that it is used as an alert system to warn the driver about approaching emergency situations. An intelligent system, based on the cognitive-motor driver model, uses information obtained from a GPS device, telematic system and command interface. The DVL+ interface predicts approaching of hazardous situations and warns about timely, using sound alarm and corresponding messages in local language of the user.

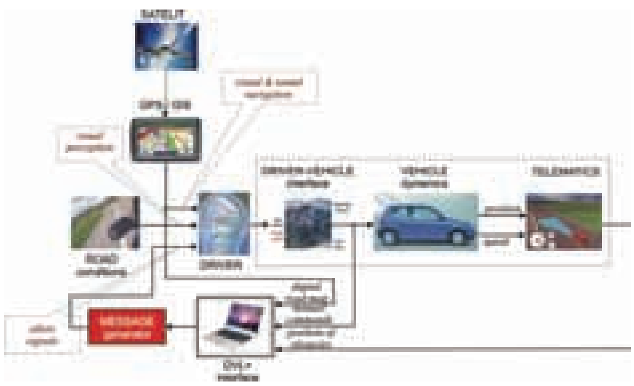


Figure 5. Emergency risk alert system operating within a GPS service pack device

The most complex and sophisticated active-safety system, based on the cognitive model of the driver, is presented in Fig.6. This system represents an automatic driver designed to enable *unmanned autonomous driving* of road vehicles in a quite automatic regime where a human driver is just a passenger-supervisor.

Based on capabilities to generate command signals for the servo-actuators of the control system, the automatic active-safety control system is capable to guide system in a quite autonomous way using necessary information from the corresponding sensory and GPS system. More information about necessary sensory-acquisition system is available in the next section. Vehicle driver is capable to choose an appropriate regime of driving. Since the system proposed in this section needs sophisticated sensory system and compensatory road infrastructure, driver chooses automatic regime if all necessary conditions are satisfied. If no, the manual regime is still valid. Of course, automatic system checks and recognizes if the conditions exist and allowed driver to enter the automatic regime. At any time the driver is allowed to take commands and responsibility of driving from the automatic system if he wishes so. For non-restricted and regular use of automatic driver system from Fig.6, the following assumptions should be satisfied:

- There is on-line GPS signal/information about the actual terrestrial position,
- There are precise digital maps of local roads (road geometry) in the region,
- There is on-line information about road conditions (damage, slippery, etc.), traffic regime (maximal speed, direction of motion, jamming, etc.),
- There is on-line measurement and acquisition of the relative lateral position of a vehicle with respect to the guiding line on the road,
- There is on-line information about obstacles on the road as well as relative distance to them,
- There is on-line acquisition of actual command signals (steering wheel angle, throttle position, braking force/torques, etc.)
- There is a possibility of on-line estimation of the coefficient of tyre-road adhesion.

The listed assumptions are realistic, bearing in mind that electronic sensor technology and estimation methods have advanced in the last decades. With an accurate model of human driver behaviour, conditions for development and application of automatic control systems are satisfied.

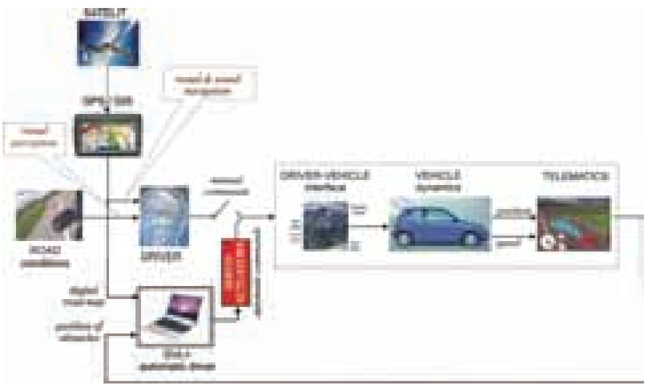


Figure 6. Advanced active-safety system for unmanned autonomous driving in the automatic regime of operation based on a cognitive-motor driver model

Implementation of the automatic driver active-safety system, presented in Fig.6, is a very delicate task bearing in mind that all responsibilities for system guidance are given to the artificial system. Because of that, in the first phase it is necessary to validate the theoretical results through extensive simulation tests in different driving scenarios. In the second phase the system proposed should be tested in real driving conditions on test roads but without passengers. High robustness and accuracy of the system have to be attained before commercial implementation in automotive industry. In that sense, in the next sections some important implementation aspects and demo-scenarios of automatic driving are presented.

Technological Background

Technological background of the active-safety system, the concept of which was presented in Section 3, assumes implementation of different sensors, communication and processor technology. An experimental system, as presented in Fig.7, can be used for verification and validation of the research results. The experimental system includes the basic sensory and communication equipment such as: GPS anntena for detection of global vehicle position on the road, 2 ultra-sound probes attached to the front bumper of the vehicle (Fig.8) for detection of the relative longitudinal and lateral position on the road, short-wave radars or laser range-finders for detection of the faced obstacles, etc. For identification of the accurate longitudinal as well as lateral position of a vehicle, different markers attached/emmbeded to the road can be used. In Fig.8, the appropriate zebra-stripe is shown used for experimental measurements. Alternatively, corresponding magnetic markers can be embedded into the road surface structure. As an appropriate detector of mobile or immobile obstacles on the road, an advanced telematic system presented in Fig.9 can be used, too. Sensory information, as well as information acquired by a communication system are led to the board-computer (micro-controller) capable to process data and perfrom appropriate safity tasks: activate alert system (Fig.5) or guide the vehicle (in the case of full automatic regime, Fig.6).

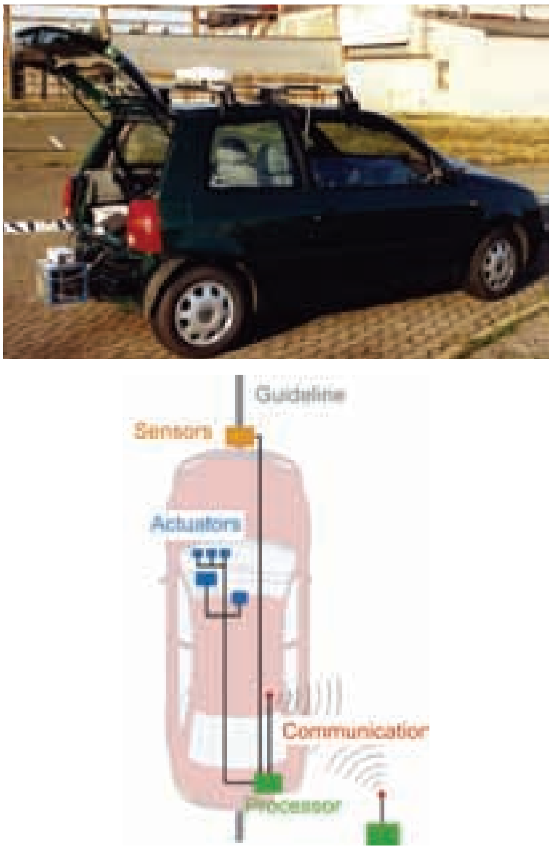


Figure 7. a) VW Lupo – test-car equipped for experimental driving (Technical University of Braunschweig, IVA, Germany), b) structure of the experimental system

Figure 8. Real-time following path experiments performed by a VW Lupo test-car (TU Braunschweig, IVA, Germany)

Figure 9. Advanced telematic system provides accurate and timely infromation about position and speed of obstacles moving on the road

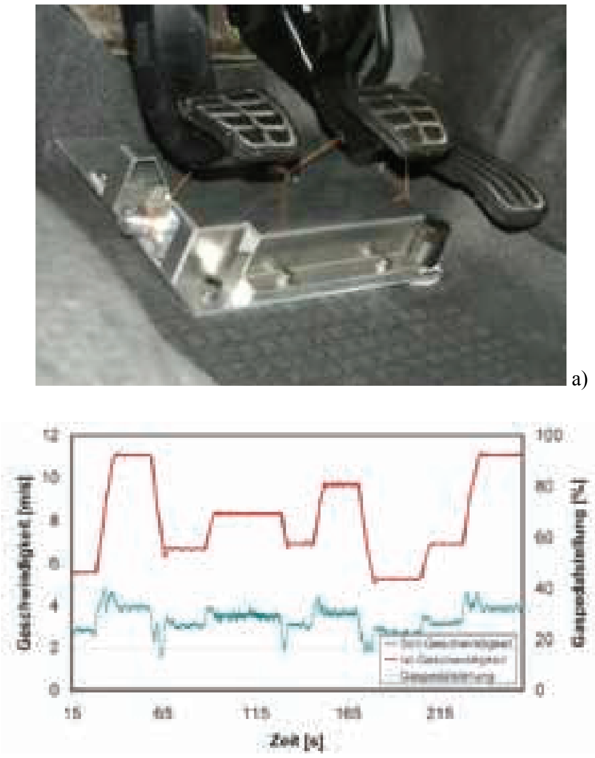


Figure 10. Acceleration- and brake-pedal servo-actuator controlled by PC-based industrial micro-controller [12]: a) operation setup, b) obtained speed and actuator power realized in one test-driving

For the purpose of building a fully autonomous system (Fig.6), special servo-actuators that replace driver manual commands are necessary. In that sense, hi-tech automotive control companies (such as [12]) have worked on design of diffrent servo-actruators for automotive industry. Some of the successfull products are commercially available (see Figures 10 and 11). Bearing in mind the active safety system the concept of which is presented in Fig.6, the servo-actuators presented in Figures 10 and 11 can be assumed as appropriate for the experimental verification of the system proposed. Having in mind the costs of organization and performance of such unmanned autonomous vehicle driving tests, the simulation tests are used as alternative in this paper. The goal is to prove that control scheme presented in Fig.6 ensures stabile and safe as well as accurate trajectory tracking in different real scenarios using paths/roads from digital maps.

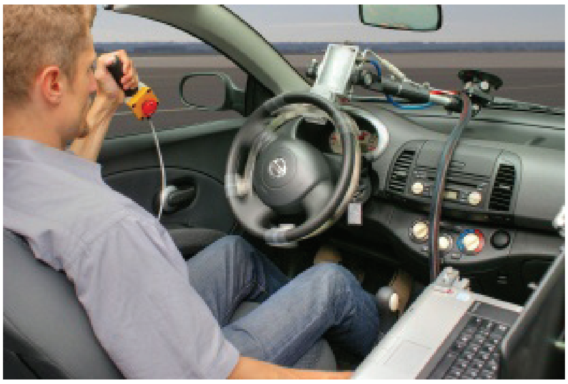
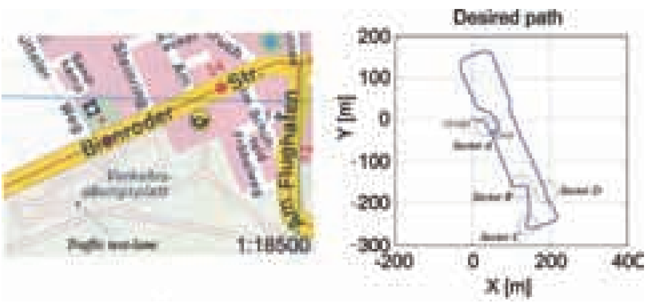


Figure 11. Steering wheel servo actuator [12] assembled to the driver command place

Simulation Experiments

For verification of the performances of the active-safety control system, the block-scheme of which is presented in Fig.6, one simulation test of running along one realistic path is performed. For that purpose, a test-road taken from the satellite-based map [13] is assumed as appropriate. Its digital map is used as a CAD model of the referent path (Fig.13) and loaded to the DVL+ automotive modelling software [8].

Figure 12. An example of a road [13] (Traffic test path, city of Braunschweig, Germany) whose CAD model is used for verification of active-safety system performances



a) b)

Figure 13. Referent path assumed in the simulation experiment: a) Fragment of the city map of Braunschweig (Germany) with a considered traffic test-lane, b) corresponding CAD model

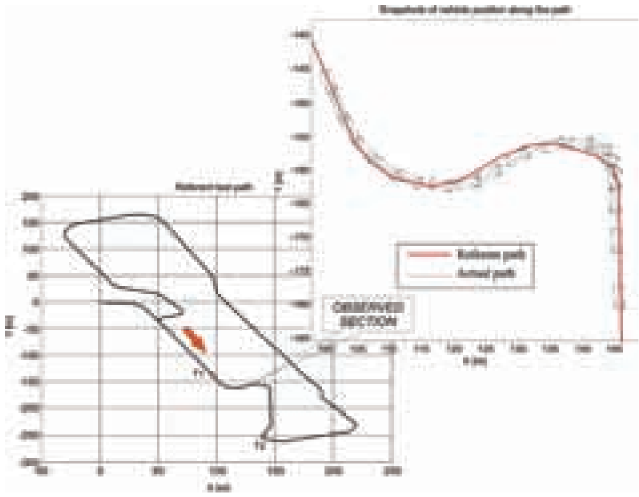
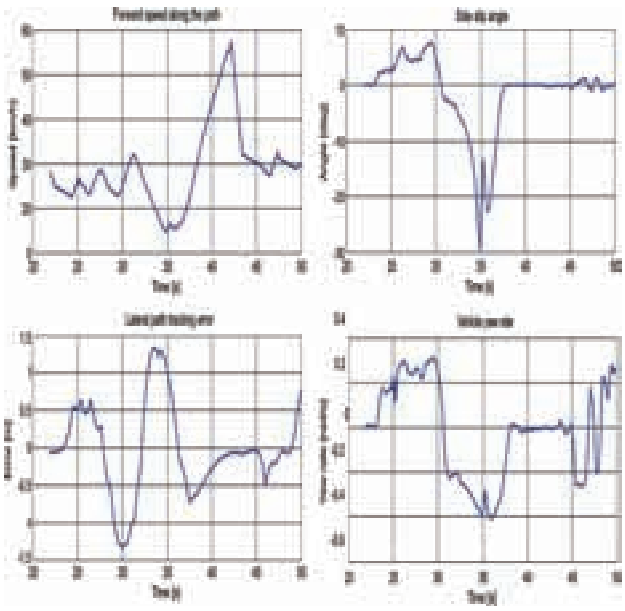


Figure 14. Computer animation of vehicle motion: (i) referent test path and (ii) successive vehicle position along the test path in the observed section

For simulation tests, a dynamic model of the VW Lupo small passenger car is assumed [14]. The curvilinear, 1176 [m] long, traffic test-lane is chosen (Figures 12 and 13) as a referent test driving scenario. Along the path, several characteristic sectors "A" (the right curve), "B" (the S-curve), "C" (the elbow-curve) and "D" (the S-curve) are specially observed. The trajectory tracking accuracy and vehicle dynamics at these sites are evaluated. The following graphs, presented in Figures 14 - 16, prove the capabilities of the proposed active-safety control system based on a driver cognitive-motor model. In Fig.14, the computer generated animation of the considered test-path as well as the snapshots (successive positions) of road vehicle position along the observed section of the path is presented. The snapshots of the vehicle (Fig.14) demonstrate on-line vehicle dynamic behaviour (certain side slipping) during motion.

Figures 15 and 16 present variables of interest as well as the corresponding command signals obtained in simulation. The observed time interval T1-T1 is marked in Fig.14. It represents a vehicle cornering manoeuvre that appears after straight line motion. The control commands, generated by the proposed active-safety controller, represent corresponding steering angles, throttle position (defined in a range $\left[0, \frac{\pi}{2}\right]$) and braking force applied to the wheels.



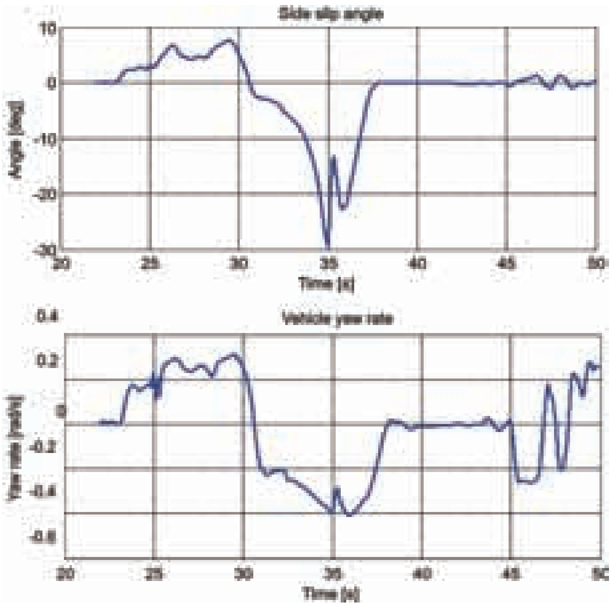


Figure 15. Simulation results obtained by the DVL+ automotive engineering software [8]: (i) forward speed, (ii) side slip angle, (iii) lateral tracking error, and (iv) actual yaw rate

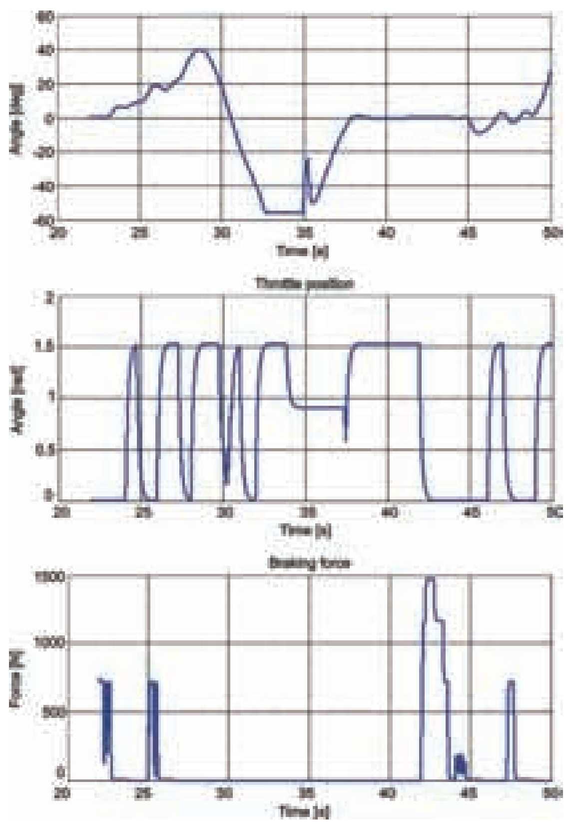


Figure 16. Simulation results [8] – steering, traction and braking commands generated by the proposed controller to replace corresponding human manual commands

Summary and Conclusion

A novel, active-safety control system operating with road vehicles is presented in the paper. An active-safety system is based on modelling psycho-physiological, cognitive-motor capabilities of human driver. Two variants of active-safety systems are presented: (i) safety alert system as an driver-assisted system helping driver to predict hazardous driving situations, and (ii) active control system enabling unmanned autonomous driving. In the second case, manual commands of the human driver are replaced by a corresponding automatic control structure. The corresponding servo-actuators and sensory system are described in Section 5, too.

The performed simulation tests of different driving conditions and running scenarios proved the high control performances of the system proposed. The next steps should be performed by testing the system with a real system and with real servo-actuators. Possible improvements can be expected in better tuning of driver model parameters according to specific driving situations.

The originality of this paper concerns development and implementation of an authentic cognitive model of human driver behaviour with road (wheel-based) vehicles. The corresponding driver model, demonstrated in this paper, includes possibilities of controlling vehicle longitudinal as well as lateral dynamics in an human-like manner, by imitating human driving skills. Contemporary solutions existing in this field of research and engineering use conventional (but not behavioural) control algorithms to guide a vehicle. The advantage of the behavioural approach, applied in this paper, is in the possibility to manage driving situations that cannot be handled (controlled) by implementation of conventional techniques (e.g. PID regulation, optimal control, predictive control, etc.).

The results presented in this paper have the significance in automotive industry as well as they can be of use for development of unmanned autonomous transport vehicles in military industry, too. There are already examples of such kind of unmanned vehicles as one presented in Fig.17. For their guidance different techniques can be used. The most commonly used one concerns the use of a GPS navigation system (e.g. [16]). The other ones, as presented in this paper, combine GPS interface, radar-based telematics as well as advanced vision. A high level of automatization and autonomy significantly depends on an available sensing system.

Figure 17. GPS guided, unmanned autonomous, wheel-based, military transport vehicle of the US army

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Do autonomnih vozila bez posade kroz izgradnju inteligentnog upravljačkog sistema zasnovanog na kognitivnom modelu vozača

Predstavljeni rad je konceptualnog karaktera. On se tiče projektovanja novih inteligentnih sistema aktivne sigurnosti i signalizacije opasnosti kod drumskih vozila zasnovanih na kognitivno-motornom, psihološko-fiziološkom modelu čoveka kao operatera. Projektovanje autonomnih vozila bez posade je izazovan inženjerski zadatak koji može biti od intersa za vojnu industriju i odgovarajuće primene kod budućih robotizovanih borbenih vozila i transportera. Modeliranje hibridnog sistema čovek-vozilo predstavlja osnovu (jezgro) za sintezu jednog inteligentnog, upravljačkog sistema za asistenciju vozaču, razmatranog u ovom radu. Modeliranje sistema uzima u razmatranje prostornu, nelinearnu dinamiku vozila i interakcije točkova i podloge kao i karakteristike psiho-fiziološkog ponašanja čoveka kao operatera. Dve varijante sigurnosnih sistema kod vozila su predstavljene u radu: (i) sistem za upozorenje namenjen obaveštavanju vozača o približavanju opasnosti odn. kritične situacije u vožnji i (ii) automatski, aktivno-bezbednosni upravljački system koji omogućava komandovanje vozilom u autonomnom režimu rada. Takođe, u radu su prikazani odgovarajući savremeni servo-aktuatori i senzorski sistem visokih tehnologija kadri da podrže funkcionisanje jednog takvog predloženog sigurnosno-upravljačkog sistema kod drumskih vozila. U radu su priloženi odgovarajući simulacioni rezultati kao primeri koji demonstriraju tehničke mogućnosti i verifikuju upravljačke performanse jednog ovakvog sistema. Na kraju rada dati su rezime i zaključak.

Ključne reči: **robotizovano vozilo, drumsko vozilo, točkaško vozilo, upravljanje vozilom, upravljački sistem, hibridni sistem, sigurnosni sistem, modelovanje sistema, rezultati ispitivanja.**

До автономных беспилотных перевозочных средств (машин) через разработку интеллектуальной системы, обоснованой на осознательной модели водителя

Настоящая работа имеет концептуальный характер, который касается проектирования новых интеллектуальных систем действующей надёжности и сигнализации опасности у дорожных перевозочных средств (машин), обоснованых на осознательно-моторной, психологическо-физиологической модели человека в роли оператора. Проектирование автономных беспилотных перевозочных средств (машин) является вызывающим заданием для инженеров и может быть от большого интереса за военную промышленность и соответствующие применения в будущих боевых машинах-роботах и транспортёрах. Моделирование гибридной системы человек-машина представляет основу (сердечник) для синтеза одной интеллектуальной системы управления для поддержки водителю, рассматриванной в настоящей работе. Моделирование системы учитывает пространственную, нелинейную динамику машины и взаимодействие колёс и дороги, а в том числе и характеристики психо-физического поведения человека в роли оператора. В работе представлены два варианта системы безопасности у машин: (и) система предупреждения о приближении опасности, т.е. непредвиденного случая в поездке, назначенная для водителя и (ии) автоматическая действующее-безопасная система управления, обеспечивающая управление машиной в автономном режиме работы. В настоящей работе тоже показаны соответствующие современные сервозаглушители и сенсорные системы высоких технологий, способны оказать поддержку функционированию одной такой предложеной системы безопасного управления у дорожных перевозочных средств (машин). В работе добавлены соответствующие результаты моделирования в роли примеров, которые проявляют технические возможности и контролируют перформансы управления одной такой системы. В конце настоящей работы добавлены вывод и резюме.

Ключевые слова: автономное перевозочное средство (машина), дорожное перевозочное средство (машина), колёсный вездеход, управление перевозочным средством, система управления, гибридная система, надёжность системы, моделирование системы, результаты исследования.

Vers les véhicules autonomes sans équipage par la construction d'un système de guidage intelligent basé sur le modèle cognitif du conducteur

Ce travail est de caractère conceptuel .Il traite l'élaboration des projets de nouveaux systèmes intelligents de la sécurité active et la signalisation du danger chez les véhicules routiers basés sur le modèle cognitif- moteur et psychophysiologique de l'homme comme opérateur. Elaborer le projet des véhicules autonomes sans équipages est une tache de défi pour les ingénieurs qui peut avoir de l'intérêt dans l'industrie militaire et les emplois convenables chez les futurs véhicules de combat et transporteur robotisés. La modélisation du système hybride homme – véhicule représente la base (cœur) pour la synthèse d'un système de guidage intelligent pour l'aide au conducteur, considéré dans ce papier. La modélisation du système prend en considération la dynamique spatiale non linéaire du véhicule et l'interaction roues/sol ainsi que les caractéristiques psychophysiologiques de l'homme comme opérateur. Deux variantes de systèmes de sécurité chez les véhicules sont représentées dans ce travail: (i) système d'avertissement destiné à prévenir le conducteur que le danger s'approche c'est-à-dire pour les situations critiques pendant la conduite et (i i) le système de guidage automatique actif et sûr permettant la conduite du véhicule dans le régime de fonctionnement autonome. Dans le cadre de cette recherche on a présenté aussi le système sensoriel moderne et servo-actuator de haute technologies à soutenir le fonctionnement de ce système de guidage proposé pour les véhicules routiers. On a présenté aussi les résultats de simulation comme exemples qui démontrent les possibilités techniques et vérifient les performances de ce système.

Mots clés: **véhicule robotisé, véhicule routier,véhicule à roues, conduite de véhicule, système de commandes, système hybride, sécurité du système, résultats des essais.**