Analysis of a driver model sensitivity to various types of distraction

F. Mars[1], A. Ameyoe[1,2], P. Chevrel[1], E. Le Carpentier[1] and H. Illy[2]

[1]1IRCCyN, CNRS, École Centrale de Nantes & Ecole des Mines de Nantes, Nantes, France
[2]Renault S.A.S, Guyancourt, France

Author email: franck.mars@irccyn.ec-nantes.fr

Keywords: distraction, driver state estimation, parameter identification, steering behaviour

Because distraction contributes to a significant number of road fatalities, a great deal of work has already been conducted to design an algorithm able to make a diagnosis of the driver distractive state. This has been mainly achieved through the analysis of the driver's gaze, steering behavior or psychophysiological indicators (Nakayama et al. 1999; Dong et al. 2011; Yang et al. 2012). Recently, some effort has been made to base the diagnosis on a driver model, by performing a parameter analysis or by analysing the model predictive performance (Hermannstädter and Yang 2013; Ameyoe et al. 2015). The present study falls into this category.

Considering that distractive activities may influence the visual sampling of the environment, the control of the steering wheel, or both at the same time, a driver model that represents the visual and motor control of steering was chosen (Saleh et al. 2011; Mars et al. 2011). The visual component of the model combines visual anticipation and compensation into a desired steering angle, which is in turn converted into a steering wheel torque by the neuromuscular component of the model. The present study analysed the two subsystems of this model in conditions of visual, visuomotor, motor and cognitive workload.

Thirty-five participants participated in the experiment, which was conducted on a driving simulator. For each trial, the participants drove around an experimental track that consisted of 20 bends separated by sections of straight road. The protocol interleaved periods of baseline driving (no distraction) and periods of distracted driving. Four types of distraction were tested: cognitive (backward counting task), visual (reading a peripheral text), visuomotor (dialing task with mandatory visual control) and motor (dialing while looking at the road). For all conditions, steering behavior was assessed by means of the standard deviation of lateral position (SDLP) and the steering wheel reversal rate (SWRR). In addition, four of the driver model parameters were identified using prediction error methods (Ljung 1999): the gain of the visual anticipation process, fed by the angular deviation of a far point (K_p), the gain of the visual compensation process, fed the the angular deviation of a near point ((K_c), the gain of a motor corrective reflex, fed by the difference between the desired and real steering angle (K_t) and the neuromuscular time constant, which represents the neuromuscular dynamics (T_n).

At the behavioral level, the results show that all distraction conditions but the cognitive one increased SWRR and SDLP, with a significantly larger effect on SDLP only for visual and visuomotor distraction compared to motor distraction. Looking at the four model parameter values, cognitive distraction did not have any significant effect. Motor distraction influenced T_n only. Visual distraction influenced T_n, K_t and K_c. Visuomotor distraction influenced all four parameters. Thus, it appears that all types of distraction can be discriminated on the basis of the analysis of parameter identification, which is an encouraging step toward automatic model-based driver state estimation.

Ameyoe A, Mars F, Chevrel P, et al (2015) Estimation of driver distraction using the prediction error of a cybernetic driver model. *Proceedings of the Driving Simulation Conference Europe 2015*, Tübingen, 13–18.

Dong Y, Hu Z, Uchimura K, Murayama N (2011) Driver Inattention Monitoring System for Intelligent Vehicles: A Review. *IEEE Trans Intell Transp Syst* 12, 596–614.

Hermannstädter P, Yang B (2013) Driver Distraction Assessment Using Driver Modeling. *Proceedings of the 2013 IEEE International Conference on Systems, Man, and Cybernetics*, 3693–3698.

Ljung L (1999) System Identification: Theory for the User, 2 edition. Prentice Hall, Upper Saddle River, NJ.

Mars F, Saleh L, Chevrel P, et al (2011) Modeling the Visual and Motor Control of Steering With an Eye to Shared-Control Automation. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 1422–1426.

Nakayama O, Futami T, Nakamura T, Boer ER (1999) Development of a steering entropy method for evaluating driver workload. *SAE Trans*, 108, 1686–1695.

Saleh L, Chevrel P, Mars F, et al (2011) Human-like cybernetic driver model for lane keeping. *In* Bittanti S, Cenedese A, Zampieri S (eds) *Proceedings of the 18th IFAC World Congress*, 4368–4373.

Yang Y, Mcdonald2 M, Zheng P (2012) Can drivers' eye movements be used to monitor their performance? a case study. *IET Intell Transp Syst*, 6, 444–452.