Correlation of Objective and Subjective Evaluation of Vehicle Handling by Neural Networks

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Abstract – The issue of vehicle handling and its assessment plays an important role in the vehicle design process. Current standard approaches are only focused on objective evaluation of standardized experiments and on subjective assessment of certain features of vehicle dynamic behavior. The presented paper introduces a set of experiments evaluated by both objective and subjective measures and an approach for correlation between them. A neural network has been trained that is capable to predict the subjective evaluation of vehicle handling based on the objective measurement of vehicle behavior during testing maneuvers.

Index Terms **– vehicle handling, vehicle handling experiments, human keywords, correlation of subjective and objective data, neural networks.**

I. INTRODUCTION

The issue of vehicle handling and its assessment plays an important role in the vehicle design process. Although vehicle handling capabilities are completely used during critical situations only which are only minor part of vehicle operation, these capabilities improve safety of the vehicle.

Current standard approaches are only focused on objective evaluation of standardized experiments and on subjective assessment of certain features of vehicle dynamic behavior. Such assessment however requires very experienced and highly trained test driver to carry out the tests and asses the subjective criteria. The problem of subjectiveness is extended due to the fact that experiments are carried out on the edge so the tests are very demanding on human concentration and even dangerous (Figure 1). Thus even repeatability of subjective assessment in longer time horizon is an issue. Moreover, the critical situation do not occur often so ordinary drivers are not used even detect vehicle handling capabilities.

So the objective methodology and procedure for evaluation of vehicle handling capabilities could improve design process and shorten testing phase ([2]), even in early stage of virtual or HIL/SIL prototype.

The presented paper introduces a set of experiments evaluated by both objective and subjective measures and an approach for the correlation between them.

Figure 1 Typical situation with the car on its handling limits during critical maneuver

The objective of the presented work is to develop initial testing and evaluation methodology for objective evaluation of vehicle handling. So the new car from similar category or modified version of the car (tyre, dampers, engine etc.) could be quickly evaluated.

The organization of the paper is following. In the section II the experiments are described. The section III introduces procedure of measured data processing and neural network design. Results and future possible steps are discussed in the section IV.

II. EXPERIMENTS WITH VEHICLE HANDLING

The experimental setup was designed based on existing methods of vehicle handling evaluation and also published attempts ([1], [2]).

Three standard, most often used maneuvers were selected for the objective measurement. These maneuvers however show the most important handling characteristics.

ISO 3888-2:2002 (VDA) double lane change test is based on ISO 3888-2:2002 and TÜV SÜD Czech s.r.o. ZM-A/07.41.2 methodology. This test is mostly used by journalists for car handling evaluation. Total length of the test is 61 m. The test driver (Figure 2) is approaching the maneuver area with constant velocity, then continues with released accelerator so the vehicle is slowly decreasing its speed during the maneuver. The input velocity is iteratively increased until

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the driver is capable to pass the maneuver without hitting the cones. Typically the input velocity is between 60-70 km.h^{-1}.

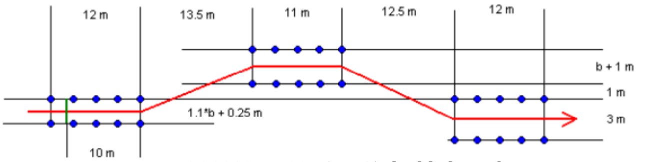

Figure 2 ISO3888-2:2002 (VDA) double lane change

Maneuver ISO 3888-1:1999 double lane change is based on ISO 3888-1:1999 standard and TÜV SÜD Czech s.r.o. ZM-A/07.41.2 methodology. Total length of the test is 110m. The test was carried out in similar way as previous one (Figure 3). However its dimensions enable to pass through with much higher velocity, typically about 120 km.h^{-1}.

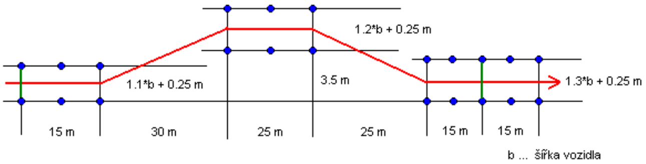

Figure 3 Maneuver ISO 3888-1:1999 double lane change

Selected physical quantities were measured and stored during the maneuver, namely angle, angular velocity and torque of the steering wheel, lateral acceleration of the vehicle, pitch and yaw angle and angular velocity of the vehicle.

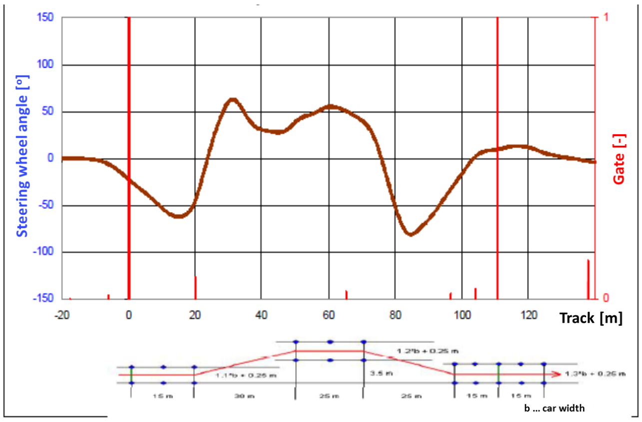

Figure 4 Steering wheel angle during ISO3888-1 maneuver of one test cars

Circular test was based on the standard ISO 4138:2004 and TÜV SÜD Czech s.r.o. methodology with gradually increasing velocity. The vehicle was driven on the circle with the diameter 60 m. Initial velocity was low to establish vehicle position on the circle and suitable steering wheel angle necessary to keep the vehicle on the track. This angle was hold and the measurement started. The velocity was increased from zero to very low velocity with minimal lateral acceleration. The steering wheel angle was the initial one. Then the velocity was gradually increased. The necessary corrections were made by steering wheel to keep the vehicle on the track as exactly as possible. The test was finished when critical velocity was reached and stability lost. The direction was to the left on the circle. Selected physical quantities were measured and stored during the maneuver, namely steering wheel angle, lateral acceleration, rolling angle and direction deviations of right front and rear wheels. All the tests were repeatedly measured three times. Example of resulting data is on the Figure 4.

Subjective tests were based on TÜV SÜD Czech s.r.o. methodology. The evaluation was done by two professional test drivers. To achieve information about possible deviation range of impression and evaluation, several experienced drivers were also invited. The complete set of evaluation criteria was too complicated for such drivers, so only limited selection of usual subjective evaluation criteria set was used. Basic properties from areas of vehicle acceleration, braking, direct driving with constant velocity, curving, handling were selected to enable even nonprofessional test drives assess them. The scale 0-10 was used.

The set of tested vehicles consisted of two middle class cars which were modified by using two sets of tyres. Four different vehicle tests were measured.

III. PROCESSING OF EXPERIMENTAL DATA AND EVALUATION METHODOLOGY

The knowledge of the measured parameters during handling experiments as the objective indicator and the corresponding driver's assessment as the subjective indicator enables to construct the methodology for determining the correlation between objective and subjective evaluation.

Based on results in [1] the artificial neural network (ANN) strategy was chosen. An ANN is computational tool which is successfully applied for solving problems usually solved by human beings. If we assume that the measured experimental data are related to driver's feeling about the handling performance, this could be considered as the input data of the driver. The evaluation of the various handling aspects by the driver could be considered as the output data of the driver. In other words, the driver maps the inputs to the outputs.

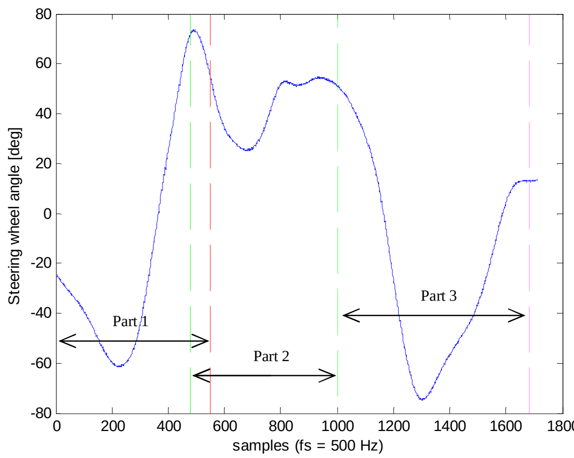

Figure 5 Example of measured data dividing

The significant inputs for tasks of vehicle handling from driver's point of view are among others the parameters measured directly on the steering wheel as the steering wheel angle and the steering wheel torque. The time behaviour of these parameters depends on the ability to reach accurately the vehicle position assigned by the driver. The steering wheel angle was chosen as the most significant input for ANN. This measured data was preprocessed to obtain a certain objective indicators by the following manner [1]. The methodology was developed and tested on double lane change experiment described above.

The measured data from double lane change maneuver was divided to the three parts where overlap of particular parts is possible. The first part is the approaching maneuver to parallel lane, the second one is the straight direction riding in parallel lane and the third part is the returning maneuver to former lane The objective indicators are the minimum values, the maximum values and the integral values for positive and negative measured signal in each part. These objective indicators must be created for each measuring experiment and it serves as the input data of ANN. On the contrary the relevant subjective indicators, and their assessments produced by the drivers, appear in ANN as the outputs. Handling aspects and example of particular driver's subjective assessments are stated in the following Table 1.

	VEHICLE			
HANDLING ASPECT	A	B	C	D
1 - Understeer / oversteer behaviour	6,00	6,00	5,00	6,00
2 - Wheel oscillation in road curve	7,00	8,00	7,00	7,00
3 - Curve entry vehicle behaviour	7,00	8,00	8,00	8,00
4 - Steering correction	5,00	6,00	6,00	7,00
5 - Road contact driver's feeling	6,00	8,00	9,00	9,50
6 - Zero position	7,00	8,00	8,00	8,50

Tab 1 Subjective indicators and example of their assessments

The ANN was trained with measured data sets of four tested cars (A, B, C, D) and corresponding subjective assessments of professional drivers. The assessments of professional drivers as the output data for ANN learning is referred to as target data.

For purpose of this research the two layers generalized regression neural network (GRNN) was chosen. This type of ANN is often used for function approximation and it has neurons with radial basis transfer function in hidden layer and linear neurons in output layer. The GRNN input consists of twelve objective indicators (four objective indicators in each of the three parts of maneuver experiment). There are radial basis neurons in hidden layer, where each neuron is associated with a car included in training. There are six neurons in the output layer, where each neuron is associated with the evaluation aspect of subjective assessment. The schematic diagram of such neural network is shown in Fig 6. The correlation results between objective and subjective evaluation has been also carried out by the radial basis neural network (RBNN) with the same training and testing data sets such as in GRNN case. RBNN is another type of neural network very similar to GRNN, but has a slightly different output layer.

Training procedure of neural network was performed by data set which consists of data from experimental measurements and assessments of drivers. Exactly this data set constitute first measurement related to the one of the three experimental ride and professional driver's subjective evaluation appears in neural network as targets.

The testing phase of learned neural network has been carried out by the input data set for testing. This data set comes from two measurements of other two experimental rides than the first one.

The proper behavior of the neural network is demonstrated by correspondence of subjective assessments in training procedure and subjective assessments derived by the neural network in testing phase using testing data of particular vehicle. For example trial task could be to recognize given vehicle according to its handling aspect assessments in comparison of drivers handling aspect assessments.

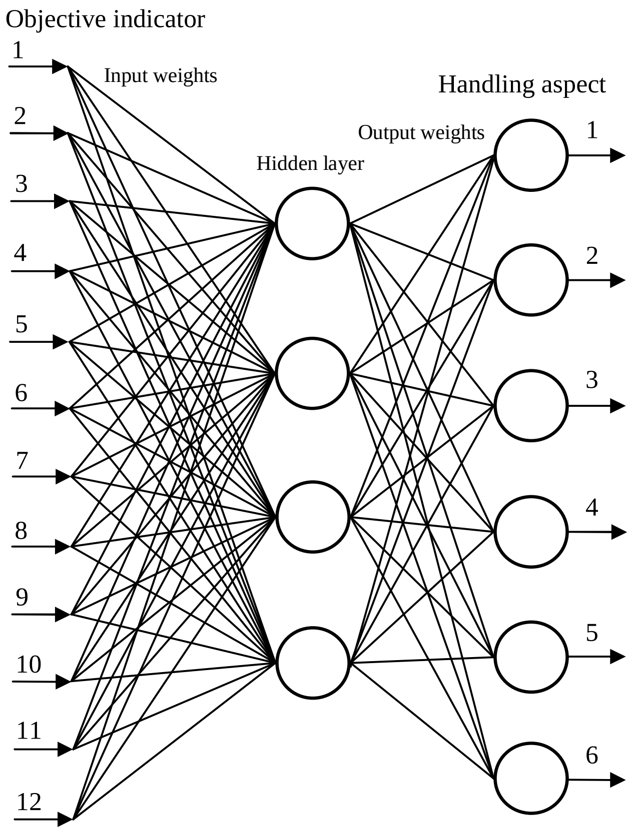

Figure 6 Schematic diagram of GRNN for vehicle handling evaluation

The results of neural network behavior are shown in Figure 7 and 8. Figure 7 displays situation using GRNN. Handling aspects assessments generated by GRNN are very close to driver's subjective assessments of matching vehicle except for third vehicle where comparatively bigger inaccuracies has appeared. The proposed technique has been also carried out using RBNN and such results are displayed in Figure 8. These results indicate good correspondence only in case of the third vehicle but not so good in the other cases. The successful solution by RBNN is complementary to the solution of GRNN.

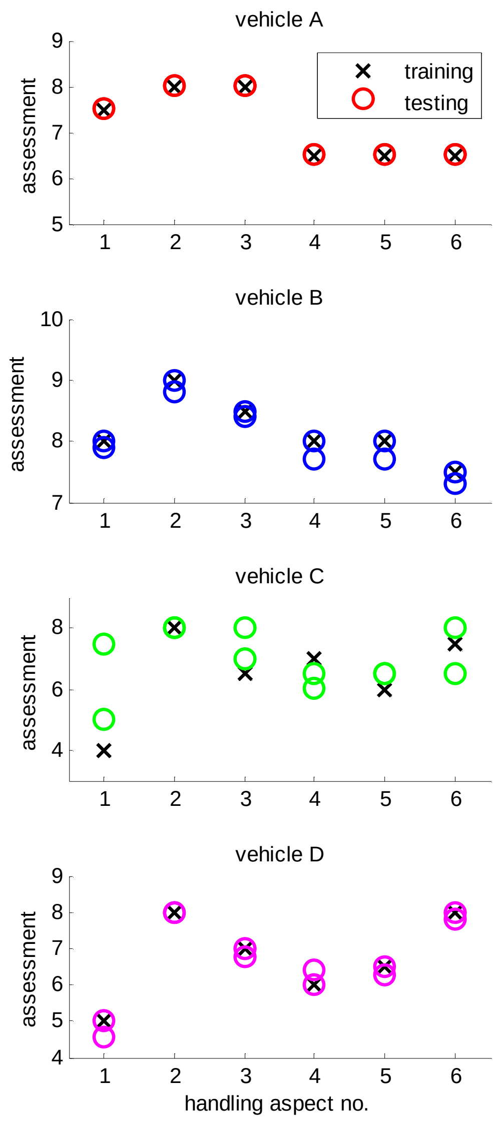

Figure 7 Results of handling aspect assessments determined by GRNN

IV. Conclusions

The paper describes both the experiments and experimental data evaluation of vehicle handling. The search for correlation between objective and subjective evaluation was based on neural networks. The experiments included wide range of maneuvers and criteria. For the initial development of the correlation method only one maneuver was selected. However, the achieved results were very good. The approach will be extended towards all maneuvers more vehicles.

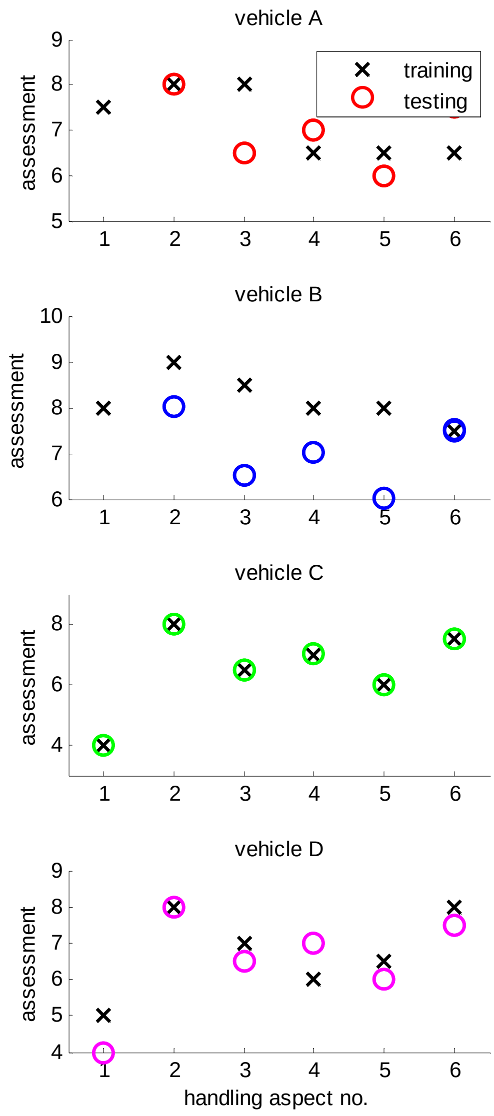

Figure 8 Results of handling aspect assessments determined by RBNN

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References

[1] Monsma, S., Defilippi, E.: Artificial Neural Networks For The Assessment Of Driver Judgement, In: Proc. of IAVSD 2011

[2] Holzmann, H. et al.: HiL simulation of closed-loop-driving maneuvers to predict the handling performance of passenger cars, In: Proc. of Chassis.Tech Plus, 1st International Munich Chassis Symposium, ATZ live [CDROM], Munich 2009, pp. 1-22