NEURAL NETWORKS - A WAY TO INCREASE THE FUEL EFFICIENCY OF VEHICLES

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Abstract: This paper deals with the possibility of creating a vehicle model using a hierarchy of neural networks. Based on this model, it is possible to build an optimization cycle that looks for parameters which are influencing the driving of vehicles along given path. The given path must include a driving through the town, out of town and along the highway section, so the test track contains the greatest number of driving modes. Data for neural network are obtained from the CAN bus and the GPS sensor. Based on the built model and given route it is looking for such route drive, where it eventually came that the development of fuel consumption is lower than in unoptimized drive.

KEYWORDS: Eco-driving, Neural networks, CAN-bus, GeoTIFF.

1   The effect of an eco-driving on vehicle fuel efficiency

Article deals with the possibility of applying theoretical knowledge in the field of the application of neural networks to implement them in design of the virtual vehicle model. This is pointing out the possibility of making the operation of the vehicle more effective from the perspective of the operator of the vehicle. During vehicle operation, it is necessary to deal with increase of efficiency of the energy contained in the fuel required to drive vehicles for the transport of persons and goods. In the EU, the road transport has the highest percentage of transported goods (44.2%) [1]. Claims for professional drivers in road haulage in terms of driving operation economy are high.

Nowadays drivers have in vehicles various assistance components, these components are able to evaluate the current condition of the vehicle and can determine the current optimal state, inform the driver how to operate the actuator such as an optimal gear. The response of the vehicle during driving on the track is dependent solely on the driver of the vehicle [2]. Such assistance systems, however cannot estimate the character of the route. This character can be represented with i.e. Speed profile of specific route.

A Dutch research team studied the effects of following Dutch eco-driving tips on fuel consumption and emissions in 2002. The study indicates that eco-driving techniques can reduce fuel consumption by 7% to 10%, depending on vehicle type (diesel or petrol) [3]. Drivers of passenger cars as well as truck drivers have some bad habits showing when driving.

They are particularly:

- Late braking
- Incorrect shifting
- Failure to comply with the prescribed average driving speed for a given route

These bad habits should be eliminated because they adversely affect the efficiency of operation of the vehicle in terms of fuel consumption and consequently kilometers shipping costs.

Economy of the vehicles is determined by the amount of fuel consumed in the driveline, which is equivalent to the energy consumption, because the energy required to move the vehicle is carried by fuel. Nowadays the main control element of the motor vehicle remains human, depends on how efficiently the driver can ride the vehicle. Therefore, professional drivers undergo various training courses about driving techniques.

Main rules of eco-driving by [4] are:

- Shift up as soon as possible
- Maintain a steady speed
- Anticipate traffic flow
- Decelerate smoothly

2   Specifying of heavy duty vehicle driving test

IVECO Stralis was selected as heavy duty test vehicle, engine used in vehicle is CURSOR10 six-cylinder supercharging diesel, with variable turbocharger geometry, four valves per cylinder, OHC, having a engine displacement of 10,308 cm^3, the maximum brake power is 338kW by 1560 – 2100 RPM, maximum brake torque 2100 Nm by 1050 – 1550 RPM. Vehicle transmission is 12 gears, electronically synchronized automatic transmission for   heavy trucks (ZF 12AS2330TD).

The European Commission in 2011 devoted to the study [5], where the average driving mode was defined for different vehicle categories based on data from individual rides. In the category of heavy duty vehicles, under defined conditions achieved by this study, vehicle achieved lowest specific consumption of 180 g/kWh to 195 g/kWh, these are the vehicles of performance classes from 353kW to 485kW. The study also found that vehicles of this performance class drive during single a driving mode from 120 to 160 kilometers at an average speed of 43-52 km/h. Driving mode is represented by driving through urban area, through rural area and along motorways.

- Urban area   - vehicle speed under 50km/h   - 21% from overall driving mode
- Rural area   - vehicle speed from 50 - 70km/h   - 15% from overall driving mode
- Motorway   - vehicle speed over 70km/h   - 63% from overall driving mode

Track determination for drive test

The test track should include motorway section part, urban section and rural section. These conditions were met by route from Bratislava, driving through Bratislava was urban section of path, the motorway section leading to Trnava and around it, rural section from Trnava went towards Jablonica on 1st class road. The highest ascent occurred between Trstín and Jablonica.

Fig. 1 shows the path in two types of view, the left view is based on GeoTIFF. TIFF 'Tagged Image File Format' image is a file format for storing raster computer graphics. This file can be used for storing information such as geo-referenced information as the coordinate system, the values of latitude and longitude and altitude, in this case, a file format is GeoTIFF, respectively DEM data. The Digital Elevation Model (DEM) over Europe from the GMES RDA project (EU-DEM) is a Digital Surface Model (DSM) representing the first

surface as illuminated by the sensors. The EU-DEM dataset is a realization of the Copernicus programme, managed by the European Commission, DG Enterprise and Industry. This data was imported to the Matlab environment through TIFF data.
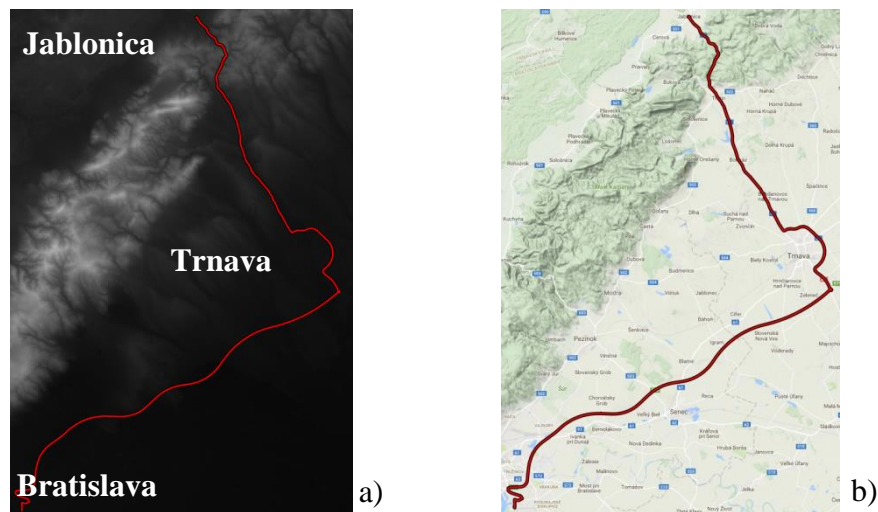

Fig. 1 The route selected for driving test
a) GeoTIFF map   b) Google Physical map

3   Data acquisition from vehicle

Getting data about the position of vehicles in the GPS coordinates was done by GPS locator u-blox NEO-6M. In case of real-time data processing is suitable converter VECTOR VN1610, which communicates with the software Matlab/Simulink. VN1610 converter is also fully compatible with CAN 2.0 A/B by Standard ISO 11898, speed of data reading is 2 Mbit/s. [7] Communication with CAN bus was ensured by a direct connection to the serial pair CAN_H and CAN_L.

| Vehicle | u-blox NEO-6M VECTOR VN1610 | Computer |

Fig. 2 Data collecting chain

From the vehicle to a computer data were scanned using data collecting chain, where the data were further processed. Based on the data from the CAN bus, a model of the vehicle, which describes the driving condition of a given path, could be designed. For heavy duty vehicle decoding messages from the CAN bus was based on FMS standard.

The data used to create the model were engine speed, actual gear ratio, travelled distance, vehicle speed, road grade profile, engine percent load, actual engine torque, the current consumption, GPS position. The values of the road grade were defined by the map based on GeoTIFF.
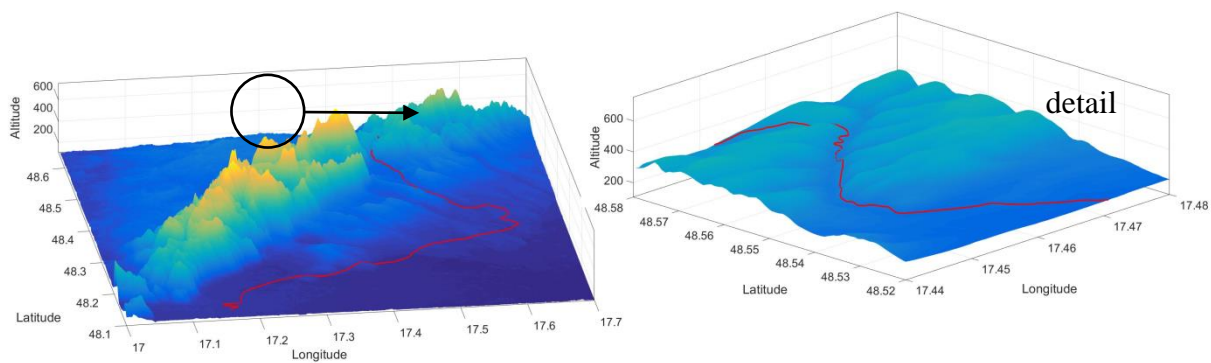
Fig. 3. Road grade data from GeoTIFF

The test path (Fig. 3) contained elevation 300m, the path measured 85 km and was traveled in both directions, which means that the total length of the path reached 170 km. The average speed of ride was 71.1 km/h towards the Jablonica, back, the average was 71.5 km/h. Speed characteristic in dependence on the traveled distance on the track towards the Jablonica is shown in Fig. 4, in the area marked as A, vehicle came to a halt and subsequently accelerating, the impact on current fuel consumption is shown in Fig. 5.
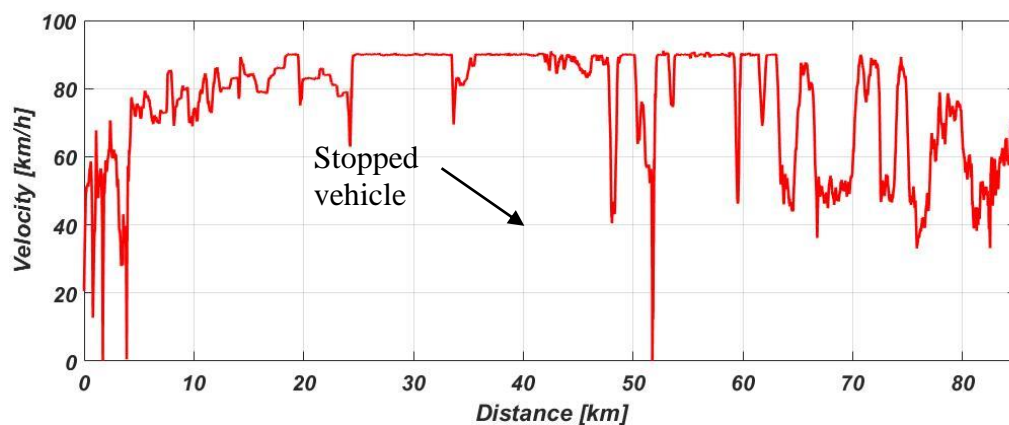

Fig. 4 Vehicle passing speed course

In this case, stopping of the vehicle is an error of driver, because it is necessary to put the vehicle in motion again. This situation has a negative impact on fuel consumption.
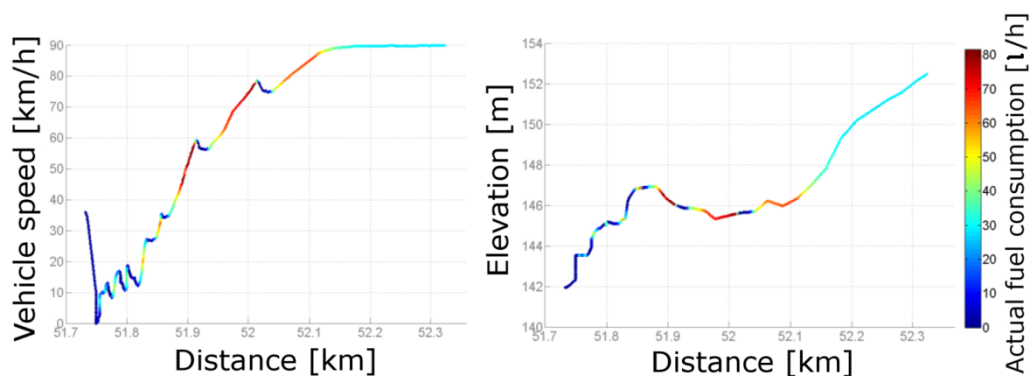

Fig. 5 The course of the vehicle speed and the altitude profile of the road,

depending on the current fuel consumption

4 The neural networks in vehicle model design

The principle of neural networks has recently begun to use more and more often. Based on ability to provide learned outputs for inputs in real time at low computational load may be used to solve complex problems, where the mathematical description of the process is difficult to describe, or is a great need for computing resources. The mathematical model using large computation power is used in papers [7-9]. Creating a mathematical model of the vehicle using neural network represents a new approach to modeling of the vehicle. The philosophy of this paper is based on the data usage which provides a connection to the CAN bus. Vehicle model is based on a certain hierarchy of neural networks (Fig.6). The input parameters to the vehicle model representing the engine speed, used gear and the data of the actual elevation. Information about the current elevation is always obtained in two consecutive values of the current altitude. These parameters are input into the system by which the driver interacts with the driving process.

Table 1. Input and output data of neural network

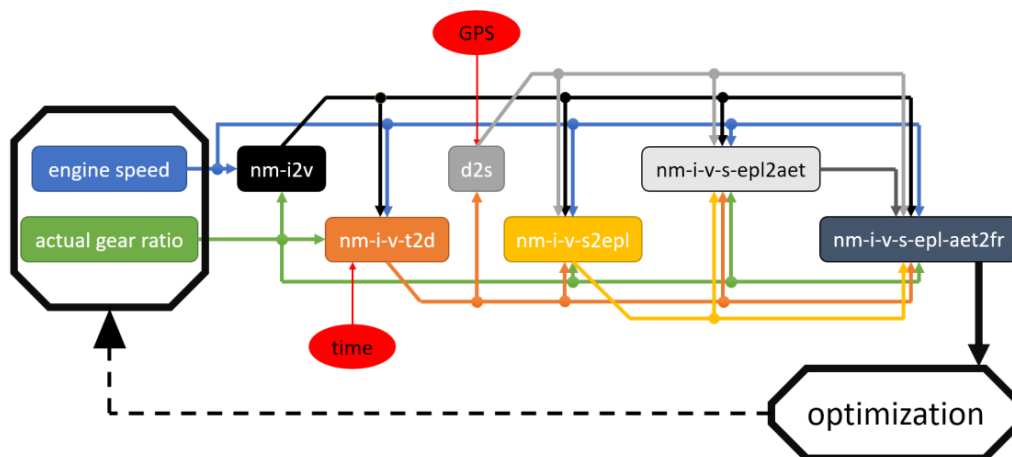| Title of NN	Input to the NN	Output from the NN
nm-i2v	engine speed, actual gear ratio	vehicle speed
nm-i-v-t2d	engine speed, actual gear ratio, vehicle speed from nm-i2v, time	distance
d2s	distance from nm-i-v-t2d, data from GPS by GeoTIFF data	road grade
nm-i-v-s2epl	engine speed, actual gear ratio, vehicle speed from nm-i2v, distance from nm-i-v-t2d, road grade from d2s	engine percent load
nm-i-v-s-epl2aet	engine speed, actual gear ratio, vehicle speed from nm-i2v, distance from nm-i-v-t2d, road grade from d2s, engine percent load from nm-i-v-s2epl	actual engine torque
nm-i-v-s-epl-aet2fr	engine speed, actual gear ratio, vehicle speed from nm-i2v, distance from nm-i-v-t2d, road grade from d2s, engine percent load from nm-i-v-s2epl, actual engine torque from nm-i-v-s-epl2aet	fuel rate

Fig. 6 Neural network hierarchy

Optimization cycle was designed so that information on actual fuel consumption is recalculated on the development of average fuel consumption and searched parameters in the form of engine speed were sought by optimization method while the final value of the average fuel consumption is not less than the predetermined value. Optimization cycle has assessed that certain sections of the path were suitable to pass on higher engine speed, so then when driving at motorway section could vehicle pass at lower speeds, or at lower engine speeds, making it possible to reduce the average fuel consumption while maintaining travel time. When passing route, which measured 85 km theoretical reduction of the average fuel consumption was from 17.5 l/100km to 15.4 l/100km, which represents a decrease of 12%. Reduced average fuel consumption was reflected in the reduction of overall fuel consumption as shown in Fig. 8, which was reduced from 16.95 l to 14.91 l.
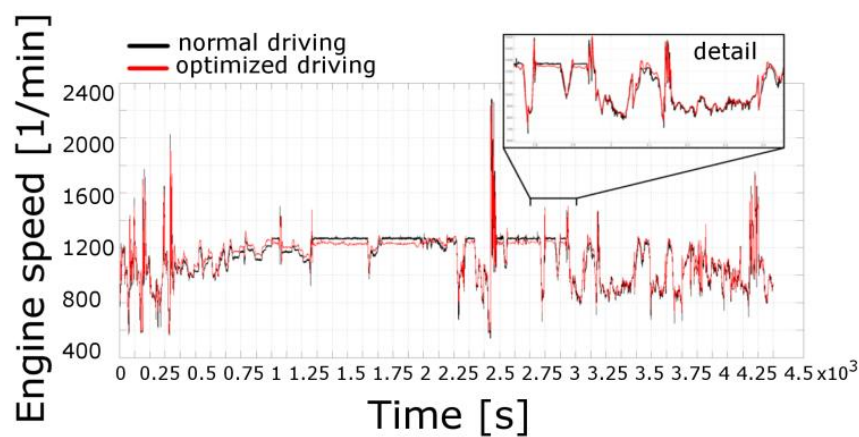

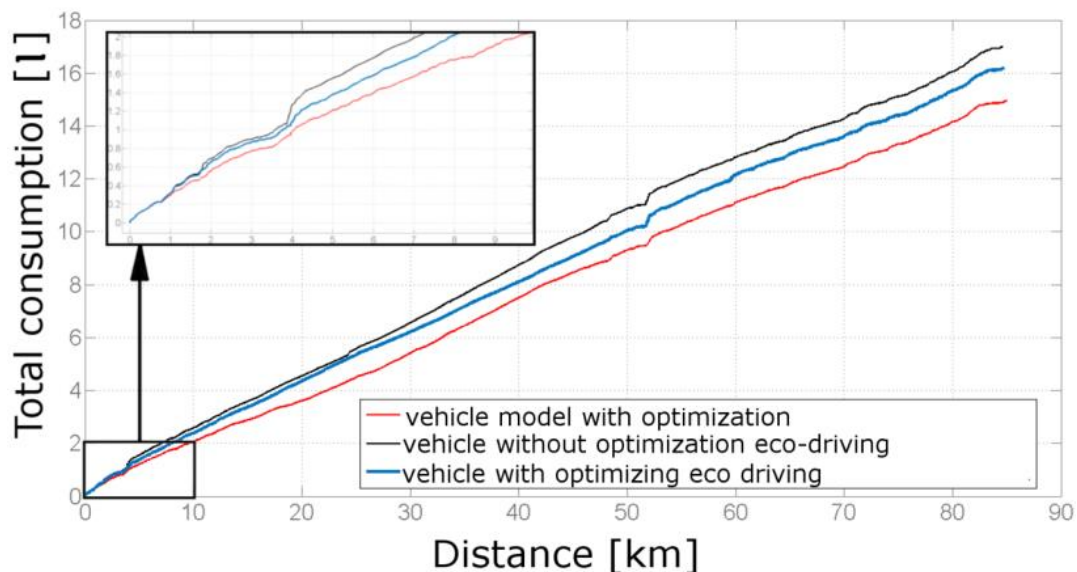Fig. 7 The course of engine speed during driving

Fig. 8 The development of the overall fuel consumption

Table 2 Evaluation of drive

Type of drive	Distance [km]	Time	Average consumption [L/100km]	Total consumption [L]
Development of average fuel consumption of the vehicle model	84.9	1:11:21	20.69	14.96
Development of average fuel consumption during test drive	84.9	1:11:32	23.11	17.01
Development of average fuel consumption verification drive	84.9	1:13:28	21.99	16.21

5 CONCLUSIONS

Average fuel consumption during the verification drive stabilized at 22 l/100km, which in consultation with professional drivers is considered as above average good fuel consumption. The resulting decline in average consumptions are reflected in the decrease of total consumption compared to the first drive. Decrease of 0.8 l in 84.9 km, which is 4.7% compared to the first drive in which data was collected to create the model. Evaluation of drives is shown in Table 2, each drive has the same path, because the vehicle always started from the same place and the end time of data recording was also approximately same. Passing time in the test drive is lower than driving of the vehicle model with optimized technique of ride. Condition in optimization cycle in Matlab/Simulink was length of traveled track.

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