MODELING OF A HUMAN DRIVER FOR A CAR DRIVING SIMULATOR

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ABSTRACT

In recent years the active safety systems in cars are becoming more popular. The number of systems that warn the driver to avoid road threats, or even take control over the vehicle are lately put in middle range class cars. During a development and verification of the systems effectiveness, a number of simulations needs to be done. However modeling and simulating only systems themselves is not sufficient to understand the human-machine operating together. Thus, there is a need to perform simulations considering man and machines regarding the human features. Most of the developed human-operators' models do not take into account an external stimuli, such as: fatigue, stress, experience or workload. It is proved that those factors directly impacts onto the operators' performance. Presented research shows the development of the new human-model including the workload and behavior parameters and its impact to the human-car system.

Keywords: fuzzy modeling, driver simulator, drivers behavior, human model, ADAS.

SpringSim-ANSS 2017, April 23-26, Virginia Beach, VA, USA

1 INTRODUCTION

1.1 Project overview

The number of systems that increase safety in cars increased significantly in recent years. More and more cars are equipped in devices and systems that inform/warn the driver before the accident. Those changes have influence on an impact conditions (Jastrzębski 2014) and directly increase the number of people using systems, which means that the “driver” we know has changed. The driver skills and behavior needs to be redefined as it is needed to adapt them to the man-machine system. Since the cars capabilities changed with more and more autonomous systems, the driver needs to know how to operate in the new environment and how to use the systems in an efficient manner. Those changes put the human driver outside the control process of man-machine system. On the other hand, the human driver is still an inherent part of the man-machine system and makes the key decisions. This is why the proper modeling of the human driver behavior is so important. During the system development and simulations, human models are not used often. In many cases, if the model is used, it does not include the individual characteristics nor parameters. Thus it makes the simulations and human model not fully corresponding to the reality. To have a complete man-machine simulation, it is need to improve existing human models.

The aDrive project is one of the first projects in Poland in terms of the research on autonomous vehicles. The purpose of the project is to develop an integrated simulation environment for testing driver-vehicle communication interfaces in various sensory modalities. The study will be conducted with the use of high-end AS1200-6 passenger car simulator and specialized software to simulate the operation of systems - sensors and control algorithms – used in ADAS (Advanced Driver Assistance Systems) driving assistance systems. The integration of environments will allow to conduct, in safe laboratory conditions, complex human-vehicle interfaces research, in respect, among the others, of the control transfer over the vehicle. One of the aims of the project is to develop and implement into the car model a set of ADAS systems. The implemented solutions will allow the car to perform an autonomous operations in virtual environment. The autonomous car behavior is similar to a perfect human-driver and all it reactions comes straight from the mathematical relations and are always repetitive and predictable. The part of work was focused on implementing a new human driver model into the virtual environment, so the simulation can be more realistic.

To develop a more advanced operator-model, dynamic change of the human parameters need to be included. The biggest challenge was to create the driver model that is dependent to the external stimuli such as workload or driver-type-behavior. Such an approach allowed to obtain the individual models as a function of external parameters. Developing of a new human model will allow to improve the simulation process and to provide a new data for automotive industry

1.2 Human modeling

The main issue that occurs in man-machine simulations is the human model complexity. In most of the research the human models are fixed parameters models. It means that they are not susceptible to external stimuli. None of the: stress factor, fatigue, experience, workload etc. affects the model dynamics. Thus the model response is always predictable and repetitive (Beaty, 1995). In the literature there is a numerous research on modeling the operator as an element that is not susceptible to external stimuli (Hess, 1996, McRuer, 1957, Kopyt 2016). There are several models derived. Most of them are represented as linear models which does not consider humans susceptibility to external factors. On the other hand the number of the psychological research, especially in aviation psychology, proved that those parameters directly impact to the human performance (McRuer, 1957, McRuer, Jex, 1968,). Which in most cases affects the systems safety (Kopyt 2015).

1.3 Safety Systems

For the purpose of the simulation only a few systems have been developed. However they cover more or less the functionality of the autonomous car in defined environments. In this chapter the ADAS systems are explained and defined.

The *ACC* – (Adaptive Cruise Control) is a system which main function is to maintain the established speed and to detect other vehicles moving on the same lane (ISO norm 15622:2002). If the system detects a vehicle in front of the car, the speed of the vehicle equipped with the ACC is reduced to compensate the distance between the cars. The key parameter is to maintain a safe, constant distance between the cars.

The *AEBS* – (Autonomous Emergency Braking System) which main functionality is to initiate the emergency braking procedure if a car is about to hit the obstacle and the driver did not notice it. Braking is preceded by the sound followed by a light signal, and finally brakes are activated with a partial force. When the system detects that a collision is likely to happen, then brakes are activated to 100%.

LKA – (Lane Keeping Assistant) is a system which is an extension of *LDW* (Lane Departure Warning) system (ISO norm 17361:2007). It function is to keep the car in the lane when the driver did not correct the position of the car. In most cars equipped with the system it works even without holding the steering wheel. Cameras detect the position of the car – where one of the lines is to be closer to the center of the car from the other course is corrected so that the vehicle remains in the middle of the lane. To proceed the integration between the systems and the human model it was needed to provide the set of input and output signals and define on which parameters human has most influence. All input/output parameters and driver conditions which affects the systems, are shown in Table 1.

Table 1: Major parameters of developed systems.

System	Input parameters	Output parameters	Driver's condition affects
ACC	The trajectory of the next car (check or going to turn vehicles move along the same lane)	Acceleration	Recognition of the distance to the next car (tired / less cautious driver will respond later)
	The speed of the car equipped with ACC	Delay	
	The distance to the next car	Maintaining a constant speed	Recognition of the distance to the next car (tired / less cautious driver will respond later)
	The speed of the following vehicle (if any)		
AEBS	The velocity of the car equipped with AEBS	Signals informing the driver when approaching obstacles	Obstacles detection
	The cameras / radar / LIDAR (or combined image all at once) for the obstacle detection	The brakes activation force	Estimating distance from obstacles
	The distance from the obstacle	Maintaining a constant speed	Estimation the obstacles velocity
	The speed of the following vehicle (if any)		Response time before the start of braking
	An obstacle trajectory		

LKA	Cameras determining the position of the car on the lane	Control wheel / position of the cross car	The time to determine the position on the lane The degree of correction of the course

The experiments and systems have been prepared in PreScan/MatLab environment. PreScan is a physics-based simulation platform that is used for development of ADAS systems. PreScan consist of a GUI-based preprocessor to define experiments and sensor models and a run-time environment. For making and testing algorithm MatLab and Simulink software were adapted. Finally the path follower system was implemented. However this parameter was adopted from the PreScan library and was not developed in the research. The path follower allows to track the desired trajectory with respect to some predefined criteria.

2 HUMAN MODEL

It is proved that human reactions and performance depends on the external stimuli and actual state of the driver (Osskarson 1999, Cowings 1996). However the relation between input parameters (workload, driving behavior, fatigue experience etc.) and output parameters are not zero/one responses (Bass 2015, Pope 1995). First, it was decided that the (simple) human model needs two basic input parameters – behavior, which is correlated with the driver type, and a workload level. The modeling or collecting the data form biofeedback was not a part of this research. Both behavior and workload have been assumed as parameters that may vary. However in this research it was not measured. The outputs from the human block are senses of the driver, so they can influent systems as described in Table 1. For the purpose of the research three basic output signals have been chosen:

- The sense of sight (V)
- Hearing (H)
- Reaction time (R)

The sense of sight is referred to as an opportunity to perceive changes in the environment, the correct road sign recognition of vertical and horizontal, as well as signals, indicators generated by driving assistance systems. Hearing is defined as an opportunity for a proper understanding of the sound signals generated by the environment (horn, other vehicles, the sound of the engine, braking, etc.) as well as through driving assistance systems. The response time is defined as the response time from the moment a man perceive / hear and correctly interpret external stimuli reaction – i.e. moving the wheel, press the gas pedal / brake, gearshift and so on (Liu 2005).

For driver simulation it was decided to use fuzzy logic. Fuzzy logic is a type of logic which uses not only 0 or 1 values (as is used in “traditional” one) but also values which lay between 0 and 1. Additionally fuzzy logic gives a possibility of using language variables as an input, and receiving language variables as an output. This type of variables is more “natural” while used for describing driver types.

Table 2: The fuzzy parameters input/output relation.

Input signals level		**Output signals level**		
Behavior	**Workload**	**Vision**	**Hearing**	**Reaction Time**
Careful	Low	Medium	Low	Middle
	Optimal	Medium	Medium	Middle
	High	Medium	Low	Long

	Low	Medium	Medium	Short
Optimal	Optimal	Perfect	Perfect	Short
	High	Medium	Medium	Middle
	Low	Medium	Low	Short
Aggressive	Optimal	Perfect	Medium	Short
	High	Low	Low	Short

As an example of using such a variable type (and fuzzy logic basics in general), a description of water temperature is often used. In a description of water temperature people more often than just “water is cold (0)” or “water is hot (1)” use “water is cool”, “rather cool”, “lukewarm”, “warmish”, “warm”, “rather hot” etc. Analogically, when a driver type description is taken into consideration, not only careful (0) and aggressive (1) should be used, but also “rather careful”, “normal”, “rather aggressive” etc. A simple model which was used in this work contained of three driver types (careful, normal and aggressive), and for each type there were three levels of (also fuzzified) workload (low, optimal and high). Using MatLab Fuzzy Logic Toolbox, for each driver type in each workload level a conditional statement was set, which (according to the Table 2) for each type – workload connection assigned different levels of the sense of sight (V), Hearing (H) and Reaction Time (R). The meaning of this levels is explained in further parts of the paper. In the Table 2 it is presented the human parameters and its characteristics. The detailed information was based on research and papers that determines the signals as a function of various conditions (Kazi 1999, Tasca 2000). Especially the definition of reaction time are widely described (Kakali 2013, Wang 2015).

3 MODEL IMPLEMENTATION

The driver-car system have been modeled in MatLab/Simulink environment. The system consist of: a car and dynamics model (taken from PreScan library and was not developed in the project), ADAS systems (developed as a part of this project), and human fuzzy model (also developed for this project).

Such a construction of the system allows to perform a basic operation as an autonomous system without human model. Then human model can be switched between input from the environment and ADAS. If we consider a human as an element of the system, we could assume that it contains of package of functionalities like adaptive systems. The only change is that it has various perception of collecting and analyzing the data. In other words, the humans’ reaction is not always the same, it is not always perfect and can vary due to some external parameters. In the autonomous system, car uses the set of the sensors that works in predefined range, and its operability is predictable. Thus, the Human-model output signal will effect on the input parameters to the particular systems. It means that due to the drivers’ state, the parameters responsible for the environment recognition would be modified in a certain manner. The human model is placed on the particular parameter and changes its value as the external parameters force it. On the Figure 1 all subsystems that human fuzzy model has is presented. The green line corresponds to the particular parameter that comes from sensors, i.e. velocity recognition, and the output from the *fuzzyfication_parameter* is modified parameter.

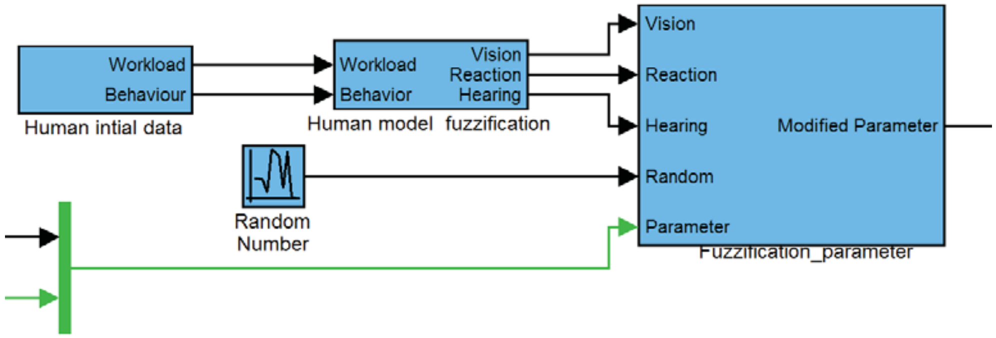
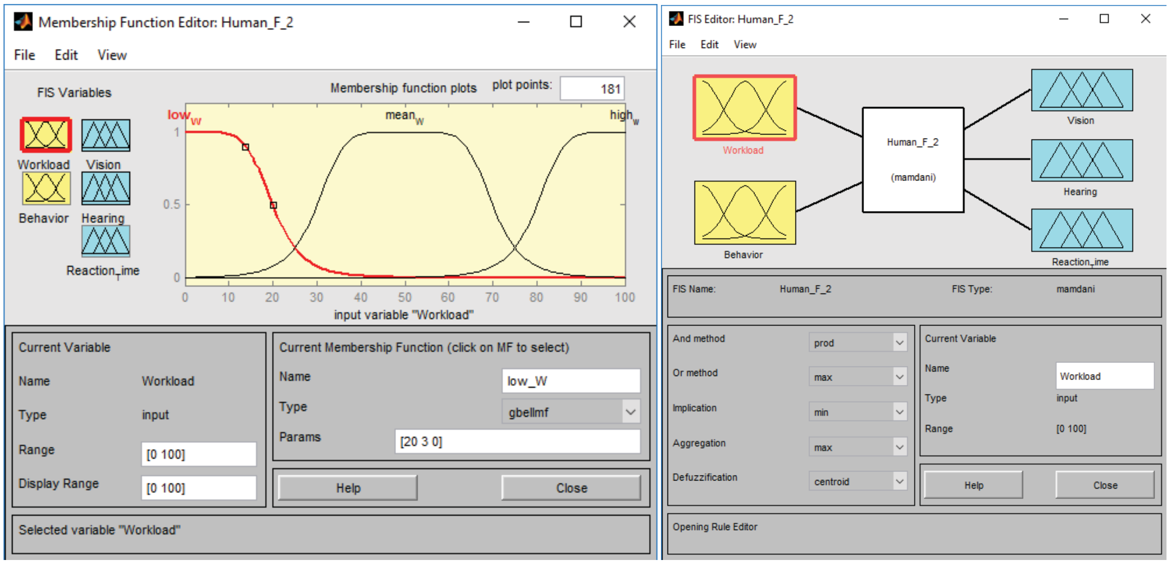


Figure 1: A Simulink human driver-car system.

The random number input is used for the second part of a fuzzy system – part which include some "randomization" of a human behavior. Its application was caused by differences between different car following plots which, even after particular analyzation, had some part described as "losing attention" in random moments. This part takes a parameter value, then "blurs" it to the range, and choses randomly value from that range. As a first approximation ranges: $1x$ to $1x$, $0.9x$ to $1.1x$, and $0.7x$ to $1.3x$ where used, where x is modified parameter. The particular range type was chosen according to values from fuzzy-system driver recognition in the beginning part.

The human model fuzzyfication block contains the fuzzy model of a particular driver. To complete the fuzzy model properly it is needed to create two main element of the model: define a membership function that represents the input signal gradation and create a rules that describes the input/output signals relation. MatLab software provides a predefined membership function shapes (Gaussian, triangles sine, etc.). That is why, in the research most common function have been applied.



Current Variable
Name Workload
Type input
Range [0 100]
Display Range [0 100]

Current Membership Function (click on MF to select)
Name low_W
Type gbellmf
Params [20 3 0]

Selected variable "Workload"

FIS Name: Human_F_2
FIS Type: mamdani

And method prod
Or method max
Implication min
Aggregation max
Defuzzification centroid

Current Variable
Name Workload
Type input
Range [0 100]

Opening Rule Editor

Figure 2: Workload membership function (left) and model scheme (right).

For an output membership function a triangular shape was used, because of the "sharp" answers for parameters change. Because in case of human describing not many things could be described using such a sensitive functions it was decided to use predefined, Gaussian shape (Nafisi 2011). The advantage of the fuzzy modeling is that a simple relations between the input and output signals that are clear to define in real life can be easily define in the fuzzy model. To be more specific it is clear that extremely high workload makes a lower reaction time and that i.e. aggressive driver has its senses very sharp. The fuzzy modeling allows to implement those rules in a very intuitive way. The membership functions determine the input/output signal shape. The most important part of this modeling element is to predict the level of the overlapping between the following signals levels. For the purpose of the experiment the classic membership functions have been used and the rules were introduced in line with the Table 1.

4 TESTS

Tests have been prepared in PreScan environment. From the set of various systems, the simulation tests were examined only using the ACC system, as it is the less sophisticated system on which driver model can be checked. One of the tests aim was to verify the methodology for one, random system. If the human model works properly, the other systems can be developed, as well. Test scenario contains two cars moving on a straight road. The first car – leading car, had given a speed profile shown on the Figure 3. The second car, equipped with ACC system and human fuzzy model, follows him with an initial velocity equal 0 [m/s] and top speed restricted to 13.4 [m/s]. Initial distance between cars was set at 5 m.

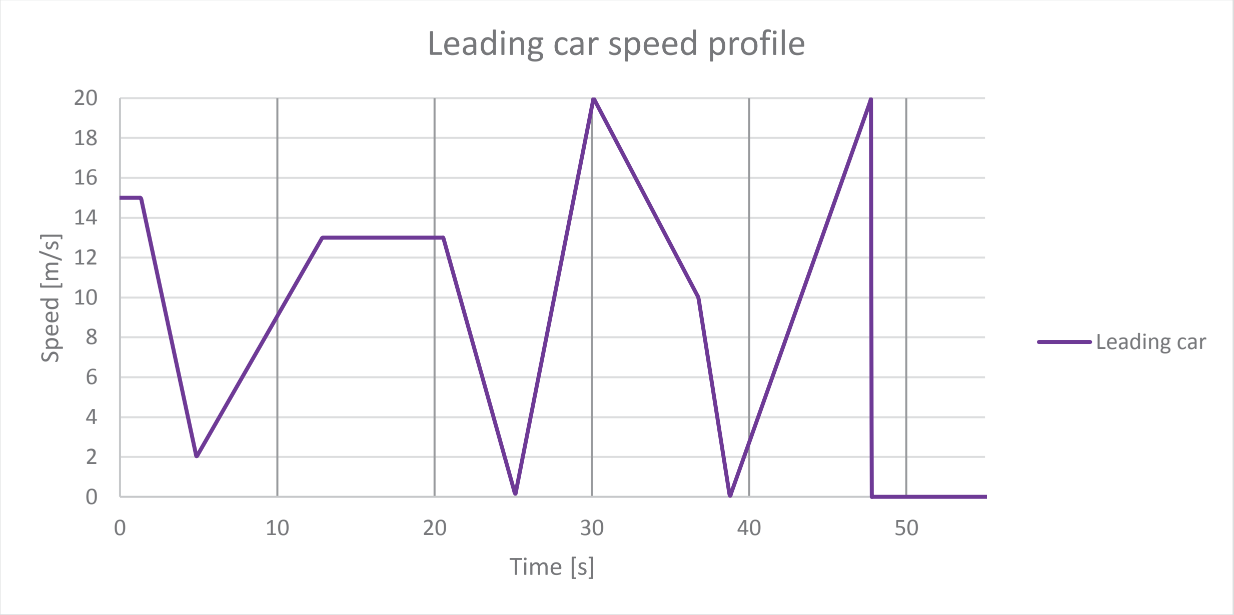


Figure 3: Leading car speed profile.

For the tests 3 types of driver have been used:

- Behavior = 1; Workload = 1: Careful driver with low workload level (bored)
- Behavior = 50; Workload = 50: Optimal driver with optimal workload
- Behavior = 100; Workload = 100: Aggressive driver with high workload level

This 3 types represents 3 totally different styles of driving, which means, that results using previously presented model should be different in most characteristic way. Both parameters: Workload and Behavior are described by the number from [0-100]. The lowest value corresponds to boredom and careful behavior respectively. The highest version corresponds to very aggressive driver and very high workload. Since in the ACC the most important "human signal" is vision. That is why, in this test the output signal, which was modified by our fuzzy system, was vision. According to Table 1, for the first one vision was medium (0.4934), for the second one was perfect (0.9225) and for third one was low (0.1333). This parameters were used in further modifications of important for ACC system parameters, in our case they were: vehicle's own velocity, next car velocity and range.

5 RESULTS

The early analysis of the results shows that change of the parameters impacts the man-machine reactions. The best plot showing differences in behavior of various driver models is a plot of a distance between leading car and car equipped in modified ACC system which can be seen in Figure 4. In this plot the orange line is a line corresponding to a model of a driver with the best conditions for driving – according to a previous nomenclature it is a model of an optimal driver in optimal workload.

Model of an aggressive driver with high workload level is one which has the highest level of error in estimating distance (between a car with this model, and a leading car), and velocity of a leading car. This leads to the less precise working ACC system and highest distortion in estimating distance between cars.

A distance plot which lays between two previously described was a plot for a model of a careful driver with low workload (bored) – according to a model it had coefficient of recognizing velocity and distance with value corresponding to the “medium” one.

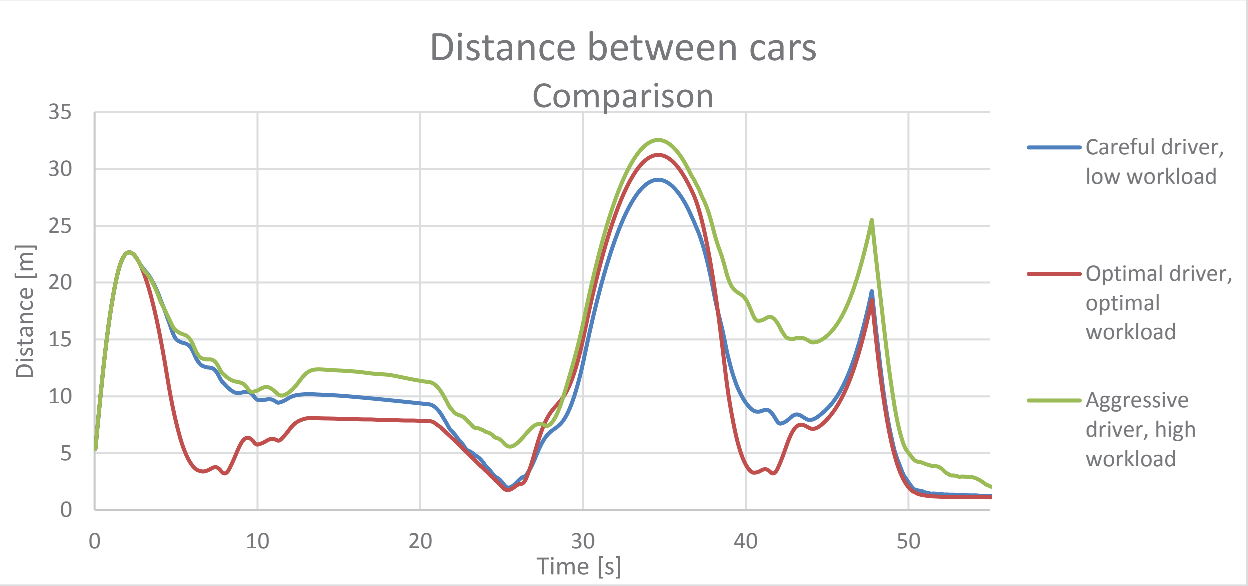


Figure 4: Comparison of a distance between leading and following car.

Plot which compares velocities between models can be seen on Figure 5 clearly shows the difference, especially around 36 second of experiment. The difference appears in a time of reacting on change of distance between leading and following car. Optimal driver model under optimal workload had the shortest reaction time. The longest has a car with a model of an aggressive driver under high workload. The difference results from the estimation of a velocity of leading car and distance to it. This estimation depends on a coefficient which is the highest for an aggressive driver model, which leads to wider possible range of velocity and distance values than for an optimal driver model. According to that, slowing down of a leading car may be read as a constant speed, so following car velocity doesn’t need to change. When a leading car velocity is lower than the lowest possible value which could be recognized as a constant speed for this car, this velocity has to be read as slowing down (or just slower) – this activate algorithms changing following car velocity. Similarly the system works for a distance estimation.

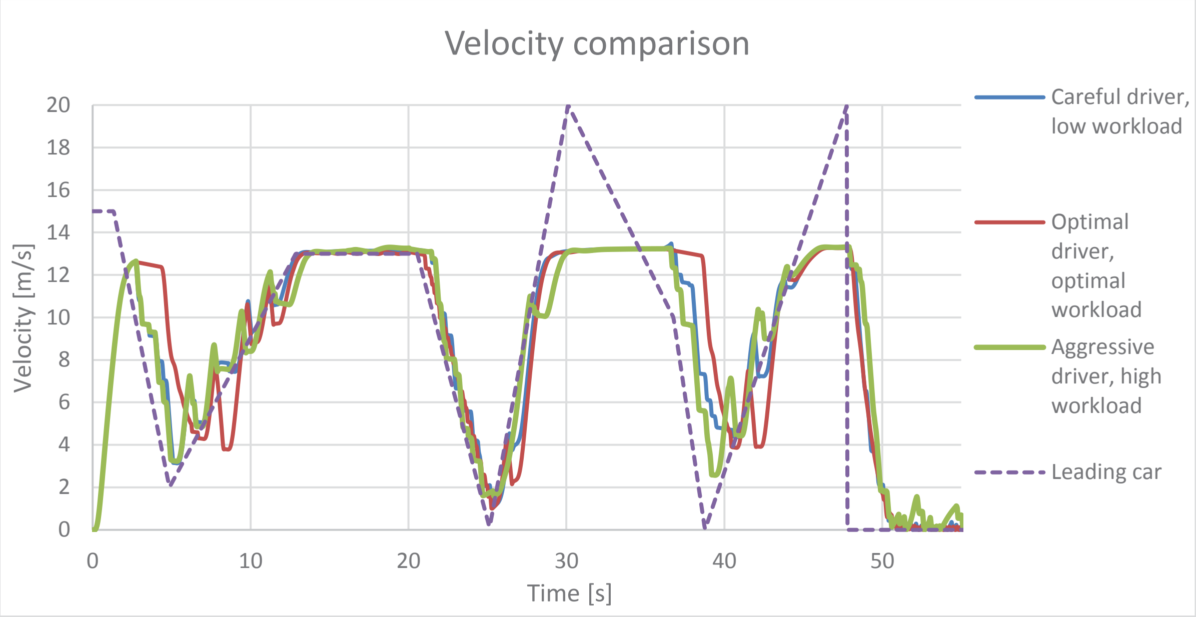


Figure 5: Comparison of a velocities between different driver models.

6 COCLUSIONS

The paper shows that the development of the human model is an important element of the simulation. The results proved that human/driver behavior and workload significantly impacts the driver performance. That confirms the psychology research that leads to statement that the human actual state directly impact the performance. Since the simulation research domain grows significantly and supports the automotive industry, the development of the human model have to progress as well. Furthermore, it seems that the fixed parameter human models are too weak for the simulation purposes and to get closer the real driver-car interaction it is necessary to develop a human models that are susceptible the external parameters. The developed model can be easily expanded with more input signals: stress, fatigue, experience, etc. In this research the measurements of the human parameters were not considered. However, the paper presents the methodology of using those data and implementing them into the driver model. Adding a set of measuring devices to collect the drivers' psycho-physiological data during the task performance would result in a very interesting research. Such an approach would lead to creation of an adaptive systems that adjust to drivers' current state. An adaptive system would then increase the efficiency of the driver-car system by changing the autonomy level and ensuring the optimal drivers situation awareness. The further work is planned to expand the human model activity and bind it with the other active systems. Such a research will provide a human model equipped with psychological state and some basic driving skills.

ACKNOWLEDGMENTS

The paper is a result of an aDrive project - "Innovative simulation technologies to evaluate vehicles driving automation systems". The results of the aDrive project can contribute to faster development of autonomous vehicles and shorten the process of implementing this technology in vehicles available to individual users. The project is implemented by ITS in the scientific and industrial consortium of with the Faculty of Power and Aeronautical Engineering of Warsaw University of Technology and the Company SEARCH-Safety Engineering Research within the Third Program of Applied Research, funded by the National Centre for Research and Development. Completion of the project is scheduled for the end of 2017 year.

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