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Andrea Benedetto

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Editorial

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It is a great honour to serve as Editor of this First Special Issue of Advances in Transportation Studies. Personally I worked hardly for the success of an idea. It was the idea of a new Journal devoted to the current progresses of studies and researches in the topics of transportation, especially oriented to the road safety. The idea of a little crew of friends became slowly a real truth. Now after one year of relevant difficulties and important satisfactions, after four ordinary issues, the first Special Issue is edited collecting and presenting some papers presented at a prestigious symposium that took place at University of California at San Diego in September. The theme of the symposium is essentially the application of driving simulation to transportation system safety.

This theme is completely close to the scope of the Journal this is why it is a special opportunity to host this selection of papers and I hope the same opportunity is for the authors to disseminate the results of significant researches developed all over the world.

I would like to put in evidence only one concept over others.

Numeric simulation came up often by the side of theoretical-empirical traditional approaches in last decades, and currently it is considered a standardized method commonly and widely adopted in many branches of scientific applications.

Basically two reasons made the success of this technique. First of all the evolution of computers and electronic tools towards unimaginable frontiers as the progress of computational algorithms to great efficiency and effectiveness. Secondly the consciousness that numeric procedures are essentially cheaper rather than traditional empirical studies and it can reach a level of generalization that is not possible through consolidated experimental methods. In fact the traditional experiments are generally reliable respecting the experiments conditions, domain and boundaries. The simulation approach makes it possible to emulate numerous different conditions and a wider domain can be investigated.

Because of obvious reasons, the first prevalent success of simulation is in the scientific field where the physically based models are dominant and stochastical components are negligible.

Subsequently and with great inertia and delay, the simulation models have been introduced also in fields where usually stochastical models are used. This evident wariness was induced by the apparent contradiction between the consolidated analysis of the probable events and the simulation of one predictable sure event. It is only apparent because through simulation so many possible events can be generated that the statistical analysis can be applied significantly over a domain of synthetical events more numerous than each possible real time history.

The question is completely different for all the processes where human factors and the uncertainties connected to decision making processes play a significant role. Human factors are a range of variables that include such things as fatigue and drowsiness, emotion, stress, distraction, effects of drugs, alcohol. They interact with individual competence to produce his or her momentary capability.

The difficulties to simulate human perceptions and reactions are crucial. Theoretical models from psychological, ergonomic and cognitive theories are useful to develop the algorithms for the simulation of brain mechanisms, but only interactive advanced technologies such as in a virtual reality environment make it possible the integration of human factors in simulation processes.

Driving is a typical action in which human perception and reaction mechanisms have a great impact. The process of decision making from a perception and the consequent actions are influenced by internal factors, coming from driver's condition, and external factors, coming from road environment.

Two main objectives stimulate to the use of interactive driving simulators. The chance to consider correctly and in an unbiased way the human behaviour and the possibility to simulate under controlled and repeatable conditions, monitoring on real time, an enormous amount of experiments at relatively low costs.

Generally writing the approach of simulation in Virtual Reality is reliable when the simulations are numerous and they are much more than the possible different scenarios or conditions of driving. In such a case the Monte Carlo methods for statistical analyses are the basic approach to validate hypotheses and calibrate assumptions.

This research context can be naturally affected by an "iper-parametrization", such as a strict dependency by a great number of parameters that is impossible to monitor and control. This is why it is crucially important the adoption of rigorous experimental protocols to assure the correct repeatability of each experiment.

Finally my opinion is that is important to underline once more that one of the most relevant added value of this approach is the high level of multidisciplinarity. This issue collects papers of transportation engineers as psychologists, mechatronics experts as doctors in medicine, electronic engineers as kinesiologists, neurologists as systems engineers.

The papers are here presented in the following review of the symposium that opens this 2004 Special Issue of Advances in Transportation Studies an International Journal.

Special issue review of a symposium on new directions in driving simulation research

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Abstract

This special issue reports on papers presented at a symposium devoted to the application of driving simulation to transportation system safety. The papers presented here range from typical highway, vehicle and traffic engineering, to the psychology of impaired driving and driver training and assessment of driver abilities. This research generally deals with the safety of drivers in response to roadway, traffic and vehicle design variables. Current research increasingly deals with computer aided engineering and design (CAE/CAD), and driving simulation is one means of studying driver behavior in controlled laboratory and clinical settings.

Keywords – Driving simulation; driver behavior

1. Introduction

Over the past decade computer aided engineering and design (CAE/CAD) has come into increasing application as desk top computing has become affordable and quite powerful. Computer applications have included roadway design [1] and safety audits of new roadway designs [2]. The capability of high speed graphics processors has also lead to increasing use of visualization in highway and architectural design projects [3]. This graphics capability has also lead to increasing use of driving simulation to address a wide variety roadway safety issues, e.g. [4, 5]. Simulation used to require relatively large and expensive facilities. Now, with the advanced capabilities of graphics processors, simulation can be presented on desk top computers with relatively inexpensive display systems [6]. It is in the context of the increasing use of low-cost and desk-top simulation systems that a symposium was recently held at the University of California at San Diego on "New Directions in Driving Simulation Research." The symposium addressed a wide variety of applications involving the highway, vehicle and driver. As illustrated in Figure 1, the roadway, vehicle and driver interact to determine transportation system safety. Driver behavior is clearly a factor in all cases. Elements of the roadway environment include geometry of the road and surrounding environment (shoulders, foreslope, etc.), traffic control devices (signs, signals and markings), traffic, pedestrians and roadside objects. The vehicle includes basic steering and speed control response properties, and in-vehicle systems that can aide in driving convenience (e.g. navigation, communication and traffic interaction) but also distract driver attention. Drivers of course contribute to highway safety in terms of their experience level and general level of capability which can range from normal and alert, to various states of distraction and impairment.

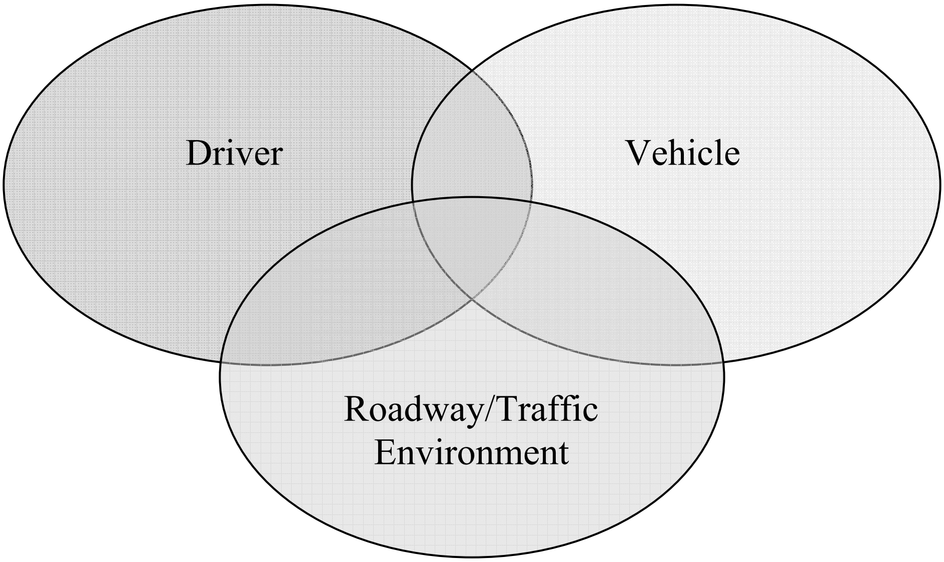

Fig. 1 – Components of the Highway Safety Problem

2. Contributions

It is in the framework of both driving performance and safety that this symposium was convened to explore the latest simulation approaches in research, development and training. Simulation papers following the general theme of transportation safety dealt with the highway, vehicle and roadway environment as follows:

"Traffic Scenarios in Driving Simulation: Implementation and Application"
This paper describes a system for modelling traffic in a driving simulation, and includes results from an experiment with a 'Traffic Performance Assistant' that is designed to enhance overall traffic flow by vehicle-dependent means. This paper discusses the importance of driving scenario design, and a user friendly interface for experimenters to define traffic scenarios. A new traffic specification module was successfully used to run an experiment on a traffic related assistance system. It enabled the subjects to experience the functionality of such a system and allowed studying their behavior in a complex traffic environment. Results of an experiment are briefly described.

"Developing Driving Scenarios for Research, Training and Clinical Applications"
This paper discusses the more general topic of the design and development of driving scenarios for various applications. This approach treats the independent and dependent variables in driving scenario design that are critical to achieving driving simulator application objectives.

"Attentional Demands While Driving in a Simulator: Effects of Driving Straights on Open Roads and When Approaching an Intersection"
This paper describes the results of two experiments designed to determine whether the mental workload imposed by intersection encounters can be assessed in a driving simulation. Overall, both experiments clearly demonstrate that it is possible to manipulate the mental workload imposed by specific driving scenarios. This paper shows that driving straights on open roads required less cognitive demands than stopping for an intersection or performing more complex lane change and doubling maneuvers. This has important technical and practical implications for studies using driving simulators.

"Driving in a Simulator and Lower Limb Movement Variability in Elderly Persons: Can We Infer Something About Pedal Errors?"
This paper describes an experiment to measure the performance of older but cognitively fit drivers relative to younger drivers. The primary measure was foot movement variability in transitioning from accelerator to brake in response to intersection encounters. This paper shows that the elderly who are cognitively fit adopt more conservative driving behaviour than younger drivers.

"Novice Driver Training Experience"
This paper describes a project designed to train novice teen-aged drivers using a simulator. The project trained over 600 drivers, and found acceptance by teachers and students at high schools that employed the system. The long term goal of this project is to determine whether simulator training can lower the high accident rate of teen age drivers. Tradeoffs in speed versus accuracy are apparent in this study as training proceeds with novice drivers. The accident rate of novice drivers is discussed, including the problem of demonstrating transfer of training by analyzing accident data.

"Long-term Stability of Standard Deviation of Lateral Position (SDLP) in Neurocognitively Normal and Impaired Individuals"
The use of lateral lane position variability has long been a favorite with highway safety researchers. It has been used in both simulation and field testing of various highway safety projects. This paper shows that the SDLP measure stays relatively constant over a long time period in normal and impaired subjects. Lateral lane position variability is shown to be a reliable measure for periods ranging from months to over a year when assessed in cognitively stable subjects. This study shows that this result is true not only for normal individuals, but also for stable medical/neurologic populations.

"Discriminating between brain injured and non-disabled persons: a PC-based interactive driving simulator pilot project"
The purpose of this pilot study was to determine whether a driving simulator could be used to discriminate between the driving performance of cognitively impaired, brain-injured drivers and non-disabled drivers. The results demonstrate that in general, discrete events such as running off the road, crashing, running a stop sign or red light, and failure to execute turns are good discrimination indicators. Continuous indicators such as speed deviation on straight and curved roads and lane position during a curve also discriminate between the two populations.

The last two papers in this special issue review methodological considerations in the use of driving simulation in the assessment of driver abilities in research studies and clinical settings as compared with other standardized testing protocols.

"The Assessment of Driving Abilities"
This paper reviews the major methodologies that have been applied for the assessment of driving abilities, and discusses their relative benefits and limitations in research studies. Laboratory measures, such as neuropsychological tests, have been used to infer poor driving skills based upon poor test performance, but have met with mixed success. Driving simulators provide the opportunity to evaluate under-addressed skills such as accident avoidance and navigational abilities.

"Driving Simulation in the Clinical Setting Utility for Testing and Treatment"
This paper discusses the potential for driving simulation in the clinical setting to test and treat impairments of visual perception, cognitive functioning and driver safety across a wide variety of conditions and age ranges. However, validation, reliability and generalizability studies will need to be done before driving simulation is widely used in clinical settings.

3. Summary

The above papers discuss a wide range of approaches, applications and issues associated with driving simulation research, training and clinical assessment. Driving simulation is finding increasing application in various research and clinical disciplines, including engineering, psychology and medicine. Simulation provides a convenient, comprehensive and safe means for training and assessing driving behavior, for evaluating new vehicle designs and for evaluating highway designs and traffic engineering concepts. Given new, more powerful and lower cost hardware and simulation software developments, these application trends should continue for the foreseeable future.

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Traffic scenarios in driving simulation: implementation and application

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Abstract

This paper discusses the use of a driving simulator to evaluate the usability of driver assistance and information systems. One system approach currently under development in the research initiative INVENT (Invent is a German acronym for Intelligent Traffic and User-friendly Technology) consists in a Traffic Performance Assistant TPA trying to enhance overall traffic flow by vehicle-dependent means. As one example, information on the current downstream traffic situation can be obtained by car2car communication technology and is used in the vehicle to inform the driver. In order to demonstrate the functionality to final customers and to assess changes in their driving behavior a research experiment has been performed in the driving simulator. The paper is structured in two main parts: The first part shows how to enhance the Stisim driving simulator to reproduce realistic traffic conditions even in congested situations. For that purpose an additional computer is connected to the Stisim system and is responsible for the calculation of the traffic scenery in a moving environment around the simulator vehicle. Longitudinal and lateral behavior of the individual vehicles is controlled by use of microscopic traffic models. The second part describes the TPA research experiment (the study with 30 subjects was performed in early 2004) and presents an overview of the results on measured changes of the individual driving behavior and the subjective assessment of the subjects concerning the TPA approach.

Keywords – Traffic generation, advanced driver assistance systems, driver behavior

1. Introduction

Since early 2000 Bosch is using a driving simulator in the Corporate Research and Development to evaluate and assess the usability of driver assistance and information systems and their impact on the individual driver behavior. The hardware and software of the equipment are based on a simulator elsewhere [1]. It consists of a local network of 4 PCs. Pedals and steering wheel are integrated in a mock-up of a vehicle's front half. The driving scenery is projected onto three front screens of 180x135 cm each, providing a total field of view of 135º. Rearview mirrors are integrated in the front image scenery. The simulator equipment has been used successfully for research studies, e.g. on speech input systems [2] or driver monitoring [3].

The evaluation of advanced driver assistance systems frequently needs complex and sophisticated traffic situations to enable the subjects experiencing the real benefits of the system concerning traffic safety or traffic efficiency. The design of these complex situations goes beyond the potential of the scenario definition language (SDL) which is used in the simulation to describe the scenarios [4]. On the other hand, an Open Module option offers the chance to include selfwritten code sections. The remainder of this paper is generally divided in two sections: the first one describes the concept and implementation details for the realization of complex traffic situations using the Open Module interface, the second demonstrates the usage of this module to run an experiment on a specific driver assistance system.

2. Traffic Generation in the Stisim Drive driving simulator Environment

2.1 Traffic Simulation

In order to run simulator experiments with traffic related systems main requirements are in reproducing realistic behavior of individual vehicles around the “simulator vehicle” and in generating specific traffic situations like congested areas with stop and go traffic, lane closing (e.g., due to an accident), etc. This has to be realized in the environment of a commercial driving simulator; a similar approach for a proprietary system is described in [5] concerning a simulator used at BMW.

The traffic situation is simulated in a moving window that starts about 600 m in front of the driver and ends 400 m behind. Different types of vehicles (cars, trucks, motorcycles) are created or deleted at the borders of this window according to the demanded traffic density. The individual vehicles have microscopic driver models for car following behavior and lane change decisions. Currently, we are using the Intelligent Driver Model (IDM), [6], to determine accelerations and decelerations, but other following models (see [7] for model descriptions) are also implemented. Situations with very slow moving traffic can be created according to data that was collected in real traffic. The velocity of the first vehicle in a “control area” about 500 m in front of the simulator vehicle is determined by the recorded data. If that vehicle is slower than the simulator vehicle and leaves the defined area the control is passed to a new vehicle that is created in front of the previous one. The velocity of the other vehicles is determined by microscopic driver models. A first version of this traffic component has been presented previously, [8].

2.2 General Concept of Computer Interaction

The simulator consists of four computers. One computes the dynamics of the main vehicle, the others render the different views of the current 3D-scenario. We use a separate computer (“Traffic Control”) for traffic calculation, that distributes the control commands for the simulated vehicles to all display computers. The display computers are extended by a module, that manipulates the visualisation of 3D vehicle objects according to the current values.

The communication scheme is illustrated in Figure 1. It is always initiated by a request of the “Center Display Computer”. The response is sent to the display computers that change the current values of the active vehicles. They store the last command that will be valid until a new command arrives. This architecture ensures that the traffic computation does not slow down the simulator (e.g. the frame rate of the display), but additional synchronisation is necessary to avoid a drift in velocity and position due to different transmission times.

2.3 Configuration Parameters

The configuration parameters are stored in a central configuration file that is read by the different components. The file includes the IP-addresses and ports of the involved computers, the specification of the simulated vehicles, the location of the corresponding 3D objects and the data files for velocity control of the leading vehicles. The vehicle specification (see Table 1) contains the type (used to define the traffic density), limitations in speed and acceleration, extent, etc.

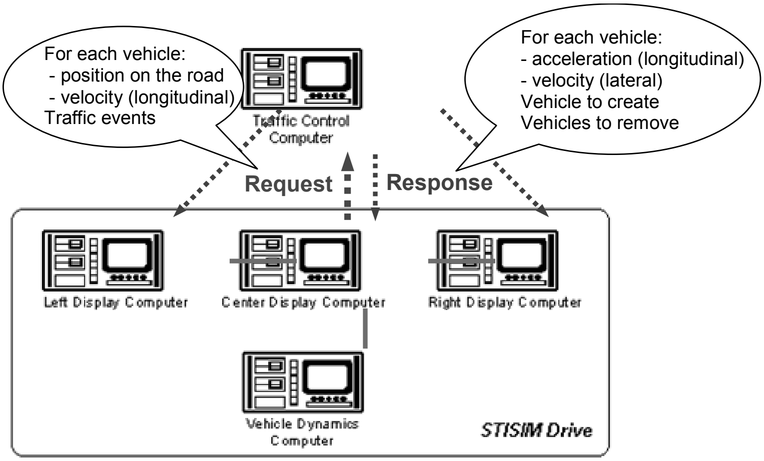


Fig. 1 – Communication Scheme in the Simulation Computer Network

Tab. 1 – Excerpt of Vehicle Specification Data File

Model...	Description	Type	MaxSpeed [km/h]	MaxAcc [m/s^2]	Length [m]	Width [m]	Mass [kg]
7	Red_Coupe	Pkw	250	5	4,4	1,7	1400
8	MotorCycle	Krad	200	7	1,8	0,8	200
9	Police_car	Pkw	220	5	5,5	2,3	1400
10	White_van	Pkw	177	3,5	4,7	1,8	2500
11	Bus	Lkw	120	2	11	2,6	20000
12	Red_Pickup	Pkw	130	3,5	4,9	1,8	2500

The data files defining the lead vehicle's velocity are specified as a sequence of values with constant time steps. Values between the defined points in time are linearly approximated. The example in Figure 2 shows a stop and go data sequence with a time increment of 0.5 s.

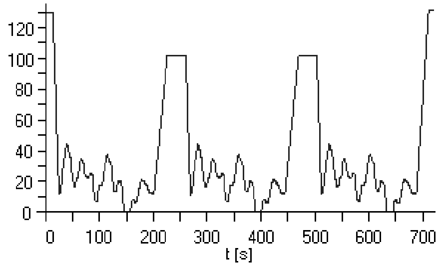
2.4 Traffic Events in the Scenario Definition Language (SDL)

Events written in SDL are the basic elements for the specification of driving tasks and overall driving scenarios in the simulator [4]. There are different types of events to define roadways, curves, hills, signs, buildings, etc. Events are generally specified as a function of distance travelled. For example:

distance 1, event code 1, attribute 11, attribute 12........., attribute 1n
distance 2, event code 2, attribute 21, attribute 22........., attribute 2n
. . . .

We use the given event ("OM") to extend the language for our purpose. When triggered this event sends all its parameters to the Open Module, where the corresponding actions can be performed. The additional traffic events and their parameters are given in Table 2.

The road parameters define the allowed behavior of a specific vehicle type. The traffic flow parameters are used to define the traffic density for each lane and a data set that can be used to control the velocity of the leading vehicle. They affect the generation of new vehicles.



Stop and go

increment: 0.5
dimension: 1440
values: 130.00,130.00, 124.60, 119.20, 113.80, 108.40, 103.00, 97.60, 92.20, 86.80, 81.40, 76.00, 70.60, 65.20, 59.80, 54.40, 49.00, 43.60, 38.20, 32.80, 27.40, ...

Fig. 2 – Stop and Go Data Sequence

Tab. 2 – Traffic Events and Parameters

Road parameters				
SPEEDLIMIT	<direction>	<limit for PKW>	<limit for LKW>	<limit for KRAD>
LANECHANGE	<direction>	<allowed for PKW>	<allowed for LKW>	<allowed for KRAD>
Traffic flow parameters				
DENSITY	<lane>	<density PKW>	<density LKW>	<density KRAD>
CONTROL	<lane>	<name>		
Modes				
SET_MODE	<lane>	<mode>		
Regions				
ADD_REGION	<lane>	<region code>	<begin>	<length>

The "SET_MODE" command switches over to one of the following modes:

EXPIRE - Default; no new vehicles are created.
DENSITY - New vehicles are created to meet the desired density.
CONTROLLED - The front vehicles are controlled by the data files.
New vehicles are added behind to meet the desired density.

Finally, a region has a defined position and extent on the road, but it has no visual representation on the simulator display. The type of the region determines the local behavior of the simulated traffic. Examples for types are "OBSTACLE" (vehicles are not allowed to enter this region), "MOVE_LEFT" (initiates a lane change) or "SYNC_RIGHT" (synchronise with the vehicles on the right lane).

2.5 The User Interface

The graphical user interface on the traffic control computer allows the operator to observe the overall scenery and to start specific actions like braking or lane changing of a specific vehicle. A snapshot of this interface is given in Figure 3.

3. Research Experiment on a Traffic Performance Assistance System

3.1 Traffic Performance Assistance

According to a study performed by the official German Automobile Club (ADAC), traffic jams on German „Autobahns" are mostly attributable to accidents (33%), road construction (31%), and inadequate capacity/excess demand (32%). The resulting losses to the economy have been estimated at about 250 million Euros per day [9].