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Unified Driver Model simulation and its application to the automotive, rail and maritime domains

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ABSTRACT

This paper describes the implementation of a model of a driver into a computerised numerical simulation. The model is developed to capture the essential characteristics and common aspects of cognition and behaviour of a human being in control of a “vehicle” in different surface transport systems, namely trains, cars and ships. The main functions of the simulation are discussed as well as the experiments carried out in different types of driving simulators to support the estimation of the parameters utilised in the numerical simulation. The validation processes carried out in the rail and maritime domains are also discussed together with a critical review of capacities and limitations of the proposed approach.

1. Introduction

The main objective of this paper is to discuss and show how a Unified Model of Driver behaviour (UMD), developed to account for general and common aspect of cognition and behaviour for all surface transport modes, has been implemented in a numerical simulation architecture, and tuned and validated with respect to empirical evidence.

The UMD is based on the concept of the “joint” DVE (Driver–Vehicle–Environment) cognitive system, where the dynamic interactions between driver, vehicle and environment are represented in a harmonized and integrated manner. The model aims to represent the interaction between Driver–Vehicle–Environment in a simple way, which retains the essential correlations between some critical “independent variables” and enables prediction of driver behaviour in dynamic and rapidly changing conditions. In particular, the model focuses on a well-defined architecture of cognitive and behavioural performance of a driver (Carsten, 2007).

The overall Unified Model of Driver behaviour (UMD), described elsewhere (Oppenheim & Shinar, 2012), is based on the concept of *parameters* which enable the consideration of dynamic behaviour and interaction between the three components of the DVE system. Five *parameters*, namely attitude, experience, driver state, task demand and culture, are considered as the basic elements affecting behaviour.

From the simulation point of view, the correlations that link these *parameters* with observable variables are open, as different domains implies different actions that can be performed by the driver and, therefore, different dependencies between variables and components of the simulation. In essence, the implementation of the UMD in a numerical simulation requires taking in consideration different interfaces between the “driver” and the other constituents of the DVE system and the dynamic/continuous evaluation of the *parameters* on the basis of observable/calculated variables at each time interval of the

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DVE simulation. For instance, a car driver has to be able to steer, while this is not required by a train driver, even if they share the same behavioural model.

For these reasons different modules have been implemented, each one adapting the generic UMD to a different domain. Fig. 1 shows how this choice has been accomplished in the simulation:

- The UMD has been implemented, accounting, at a higher level, for common aspects shared by all types of *driver*, including parameters representing mental status and the reciprocal correlations affecting their values.
- At a lower level, specific models of drivers, defining particular behaviour for distinct domains are provided, focusing on domain specific goals and tasks.
- The same strategy is adopted for the models of the *vehicle* and the *environment.*

In Fig. 1 the full hierarchy of the models is shown, where dashed arrows represents the interactions between the three topmost level models (in red) and between the train related models (in green).n this paper, the way in which the numerical simulation of the UMD has been developed will be discussed in detail. Then, the specific tuning process carried out for the automotive and rail domains will be presented. This process enabled the introduction of the above mentioned differences in driving tasks while retaining the overall architecture and modelling characteristics. The validation process with field experiments and the extension to the maritime domain will be subsequently discussed. Finally, achievements, future research and differences compared to other existing micro-simulation approaches will be discussed.

2. Simulation of the unified model of driver behaviour

2.1. UMD simulation within an Overall DVE architecture

System modelling requires knowledge of theories and conservation principles, which must be combined with imagination and vision about ways to manage the resulting formulations and equations, in such a way that they are solvable and enable to predict dynamic behaviour, given certain boundaries and initial conditions. In most domains, e.g., nuclear physics, thermo hydraulics etc., the equations and correlations resulting from the theoretical modelling of systems and phenomena cannot be solved analytically and require simplifications of various nature by linearizing the dependencies between variables and coefficients, or by making strong assumptions about the overall behaviour of components.

Simulation development is the process by which a model is further reduced in terms of complexity by transforming the equations and correlations of the model into numerical algorithms, which are then implemented in a computer program, used to actually predict system dynamic behaviour.

Modelling and simulation are necessary in order to obtain a prediction approach that preserves the essential elements of the theory, while enabling to calculate system behaviour in a reasonable amount of time and computer power. In many cases, modelling and simulation are not two separate sequential processes, but a certain amount of iteration between them is necessary. This ensures that an adequate balance is kept between the need to capture the essential behavioural characteristics of a system and the need to calculate the system's dynamic evolution, given boundary and initial conditions, in a simple and fast running way.

There is a crucial step in the process of modelling and simulation that consists of the identification of the *parameters* and *correlations* which are most relevant and which enable combination of model variables into a description of the real behaviour of the system. As mentioned earlier, the *parameters* are quantities that enable to characterise the driver model, whereas the *correlations* are relationships between the *parameters* and some observable "independent variables" that characterise the human–machine interaction. These correlations are normally developed from an extensive number of experiments and field tests of various nature, as well as appropriate and accurate data analyses. The dynamic nature of the human–machine

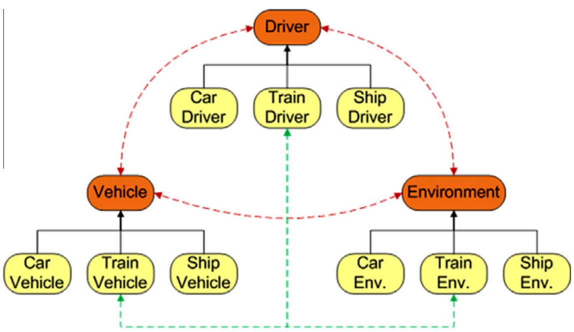

Fig. 1. Simulation architecture of the UMD in a DVE system interaction.