Driving simulators validation: the issue of transferability of results acquired on simulator

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Introduction

Simulators became little by little, and in a inescapable way, a mean to improve the knowledge in the field of driving behaviour. The investigations which can be led with this type of tool concern in particular the driver's behaviour, the conception of vehicles and of road infrastructures.

In the field of driving training the simulator tool is also more and more used, notably for the initial training and the retraining of professional drivers of trucks or special machines (forklifts, cranes, excavators but also combined harvester, wood feller buncher...).

The advantages of the studies on simulators are numerous: lack of risk, reproductibility of the situations, strict control of the parameters, time saving, costs decrease.

However the simulated driving situation is often quite far from the actual one due to numerous limits in the simulation of the virtual environment, which limit the ecology of the proposed situation. Furthermore, the lack of risk when using a simulator is a major difference between the actual world and the simulated one.

The question of the validity of the results acquired on simulator, and of the transferability towards the actual situations is thus clearly put. This question is crucial if we want to give credibility to the use of simulators, whether for the study of the behaviour or for training.

The answer is not coarse. The tool, which cannot be generic because of its limitations, must be adapted to the use and validated for this specific use. From this point of view, the recent so-called "hi-fi simulator" raises questions because this "label" is not defined and cannot, in any case, be it only compared to an identified usage.

The objective of our document is to review the problems of validation and to propose the emergence of "good practices" of usage. We first of all remind the physicals rendering limits of simulators, we then tempt a classification of the uses, then we discuss validation problems, for each use. We conclude with the necessity of an ethics of use, made more and more necessary by the current and the future possibly wide distribution of the driving simulator tool.

Limits of the physical rendering

It is at present impossible to render with realism a certain number of phenomena (accelerations, brilliant dynamics, etc.). The design of simulators thus lean on the use of tricks to produce the embedding and the carrying of compromise to guarantee a coherence of the produced sensations.

Accelerations

The mobile platforms have been used for several years for aeronautical simulators. The used technology (platform Gough-Stewart with six degrees of freedom) is sufficient to simulate the accelerations felt in flight on a plane. The technique used to produce the illusion of acceleration is "tilt coordination" (tilt of the platform, thus the internal sensors are "deceived" and the driver interprets the gravity as an acceleration in two directions) [Parker 85].

The simulation of movement in car is more complex than in aeronautics, because of the frequency of occurrence of the phases of acceleration and deceleration, as well as the important dynamics of these phases. An supplementary complexifying element results from the contact with the pavement and the inferred effects (inertials connected to the mass of the vehicle but also high frequencies connected to the characteristics of the road).

Two very simple examples allow to put in evidence the problems put by the rendering in the scale 1 of the accelerations:

1. The rendering of the braking. A braking up to the stop from a 100 kph speed requires approximately 100m (order of magnitude). The rendering on the scale of the braking would require a movement of the subject of 100m...
2. The urban situations. It is frequent in urban situation to carry out multiple changes of lane and\or, for example to carry on a change of way followed by a bend in 90 °. The realisation of 2 linked changes of lane would require a movement about 7m in side, that of the linked the change of lane and the bend approximately 15° on 20m radius

As an example of the solutions used for the depiction at scale 1, we can quote the Shinkansen simulator for passengers (Japan Railway). This simulator notably uses a side axis of 28m to return the accelerations undergone by passenger in curves (to find accel felt in curves cf. Suda?).

Visualisation

The display in simulator is limited by the graphic engine, by the rendering devices and by the underlying models. These limits concern on one hand the resolution, the luminosity, the colorimetry and the frequency of rendering and on the other hand the calculation in "real time" of the effects of light distribution, notably for the meteorological situations "not by clear time".

The current devices allow a resolution of rendering about 10cpd (cycle per degree), while the visual performance is about 30cpd. The dynamics of projectors luminosity is about 100 cd/m² while the one connected to the sun illumination is roughly 10000000 cd/m². This point induces a reduction of the contrasts. The spectrum of colours is not covered, thus the shown colours are not faithful [Dumont XX]. The frequency of restitution, even in 60hz, induces the jerky movement.

Because of these numerous constraints, the visibility on simulator is very limited (we consider that a panel of speed limit is read, by clear time, in 80m on simulator, while it is it in approximately 200m in the reality). The overtaking on a bidirectional road in 2 ways is almost impossible to simulate because of the "weak" visibility.

The modelling and the real-time rendering of the static and dynamic lightings is an important problem. The "classic" methods, based on the techniques of ray-tracing, are not usable in real-time. Solutions exist for lights carried by the subject vehicle (with limits in the case where lights enlighten a enlightened place, enlightened motorway for instance), and for the simulation of the situations of fog with traffic [renault, VOIR]. The question of the lights of the traffic vehicles remains asked.

Usages

Driving simulators are used for different needs, and the simulators drivers population is different too. We can draw up the following table:

Kind of usage Types of drivers	Vehicle behaviour	Human factors	Training
1- professionals			
1.a - With possibility of learning how to use the simulator	X		
1.b - With few possibilities of learning how to use the simulator		X	X
2- ordinary people		X	X

We distinguish the professional drivers (car testers but also professional drivers) from ordinary drivers for whom driving is not the main occupation. Among the professionals we distinguish those for whom the simulator is a working tool (car testers) and those for whom it is a tool used in a connex way, for example during training courses (professional drivers).

A professional population is generally considered more homogeneous, and the use of simulator can be mandatory. These characteristics explain its identification as group.

The professionals for whom the simulator is a working tool can learn to use the simulator (and for example to avoid the simulator sickness) and to understand the modalities of the transfer of the results acquired towards the reality. It is the reason of their identification as group.

We must note that for this group the techniques of embedding can be more intrusive (use of virtual reality helmet for example).

Validation

Two schools coexist concerning the validation of driving simulators:

1. Intrinsic validation
2. Validation by objective.

We find here globally the split designer / user. The designer tries to demonstrate that his tool is intrinsically valid, the user tries to verify that it is relevant for the intended usage.

Intrinsic validation

The question here is to prove that the simulator is "valid" by comparing the results obtained in simulation and those obtained in actual situation. Because of the impossibility evoked earlier to render the totality of the dynamics, one uses mostly transfer functions (mostly a factor of scale).

According to this approach the simulator is valid if, for example, the accelerations caused by

such operation correspond (in the function of transfer near) to the one caused by the same operation in the actual world.
The simulator is said "hi-fi" (it is this school which uses this appelation) if the error virtual / real is small.

Validation by objective

The question here is to verify the relevance of the tool for a particular usage (study of the driver’s behaviour or training). The object of the study is the human and not the simulator, which is considered here only as a tool. We can study separately the case of the behaviour study and the case of the training:

1. Study of the behaviour - the question here concerns the validity of the tasks carried out by the driver and their transferability towards the reference situation (the real situation). The simulator is considered as valid for a given situation if the driving task is "equivalent" to the one carried out in actual situation (at the tactical and operational levels as well as in terms of workload).
2. The aim is to teach the trainee, or to train or retrain a driver. The simulator is considered as valid if the experiences are transferred in the actual driving.

Discussion

Driving a simulator is quite far of driving an actual car due to numerous differences in the situations. It is not possible, for example, to reproduce the physics, notably in the visual and in the accelerations domains. Therefore, every simulator is a specific compromise dedicated to certain number of usages. It is not possible to talk about validation without mentionning the usage and the population of drivers.

A simulator professional can learn, during an adaptation phase which is often long, how to transpose from the virtual situation to the actual situation. He adapts himself to the defects of the simulator which he uses, and learns to apply dynamically transfer functions, which allow him to transpose into the reality. He also learns to compensate for the sensory incoherence and to avoid simulator sickness. The simulator can thus be used for vehicle design. For this use the designer can skip a certain number of elements of the road context, and on the global coherence of the rendering.

An occasional simulator driver has by definition no opportunity to become used to the defects of the tool. The training course or the experiment are limited in time. Thus the simulator must be conceived in order to privilege a grip in hand as easy as that of an actual vehicle (in a limited time) and to focus more on the relevance of the proposed situation (situation ecology) than on the physical fidelity of the underlying models. The question of the driving task, of the workload of each sub-task (guidance for example), must be carefully studied

Conclusion

The simulators are nowaday used for various applications. The limits in the driving situation simulation make impossible a driving on simulator "ecologically realistic". The “full purpose” simulator is for the time being a myth. Every simulator is a prototype dedicated to a particular application, which stems from a certain number of compromises.

The validity of a simulator cannot be defined without reference to its use. The problem is very different wether the simulator drivers are professionals using regularly the tool, or ordinary people using it in a coincidental way.

The transfer of the results acquired on simulator towards the actual situations is an essential question. The resemblance of the driving task (from the cognitive point of view and from the point of view of the mental workload) must be verified in the same way as the performances.

The definition of good practices (scientist ones?) of use of the driving simulation must be encouraged, a think tank on the subject would be relevant.

Except if one is able to reproduce the phenomena in the scale 1, the naming "hifi" is misleading and should be discouraged.