DRIVING SIMULATION FOR VIRTUAL TESTING AND PERCEPTION STUDIES

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Abstract

The use of driving simulation for vehicle design and driver perception studies is expanding progressively for the last ten years. Simulation saves indeed vehicle engineering cost and time and can be used for studies of road and traffic safety as well as human-vehicle interactions. The question - how applicable driving simulator is to the studied subjects - remains however still open because of several limitations in the fidelity to describe the studied phenomena.

On the one hand, the available computational modeling may be only a limited approximation of the studied vehicle behavior, because of the non-linear characteristics of the road contact (tires) or of the different vehicle systems and components (ex. Power-train, and aerodynamics),

On the other hand, psychophysical studies have revealed an important role of vestibular cues in speed and acceleration perception as well as steering which is still often out of reach for high-fidelity rendering.

In spite of these limitations driving simulation is expected to gain a major role in both vehicle design and perception studies. The recent advent of a dramatically different approach in vehicle engineering and driving (electric and hybrid vehicles, ecological driving, environment friendliness) will make necessary the use of driving simulation technology and methods for the rapid and cost efficient vehicle design.

Résumé

L'utilisation des simulateurs de conduite pour le développement des véhicules et les études de perception humaine n'a cessé de s'élargir depuis une dizaine d'années. La simulation permet de réduire les délais et les coûts d'ingénierie de véhicule et peut être utilisée pour des études sur la sécurité de la route et du trafic ainsi que sur les interactions humain-véhicule. La question - dans quelle mesure la simulation de conduite est applicable aux sujets d'étude - est cependant ouverte en raison des limitations dans la capacité des simulateurs à restituer les phénomènes étudiés de façon représentative.

D'une part, les modèles de calcul disponibles peuvent être une approximation limitée du comportement du véhicule étudié, à cause des caractéristiques non-linéaires du contact au sol (pneus) ou des différents organes du véhicule (ex. GMP et aérodynamique).

D'autre part, des études psychophysiques ont montré l'important rôle joué par les stimuli vestibulaires dans la perception de la vitesse, de l'accélération ainsi que de la direction dont le rendu reste encore souvent inaccessible à un niveau de fidélité satisfaisant.

Malgré ces limites, la simulation de conduite devrait gagner un rôle majeur aussi bien dans l'ingénierie automobile que dans les études de perception humaine. En effet, l'avènement d'une approche radicalement différente, dans la conception et dans la conduite des voitures

(véhicules électriques, conduite écologique, conception environnementale), rendra nécessaire l'utilisation de la technologie et des méthodes de simulation de conduite pour une ingénierie rapide et efficace.

Motion perception and vehicle driving

Vehicle driving is a task which is generally considered as essentially visual. Nevertheless it is well-established that other sensory information such as that provided by the vestibular and proprioceptive channels also contribute to the perception and control of self motion (Kemeny A. and Panerai F., 2003).

A psychophysical theory of perception was proposed in the first half of the XXth century (Gibson J.J and Gooks L.E, 1938) for automobile driving, defining a field of space, in the middle of which the driver is aiming to drive. Gibson described the visual perception of space (Gibbon J.J., 1950) as based on visual depth, distance or orientation stimuli available. *Optic flow*, one of the most important visual cues he proposed, is defined as a result of driving represented by the dynamic pattern of information available in the optic array along a moving pairs of viewpoints, playing a dominant role in the control of heading (Lappe et al., 1999) and collision detection (Lee N.D., 1976; Tresilian J.R., 1999).

Gibson's theory also included a definition of the perceptual field of the space itself, bringing to the driver kinesthetic and tactile cues. The underlying ideas were applied to driving simulation from the 1980s (Nordmark S. et al., 1984; Drosdol J. et al., 1985) and since then many simulator experiments have been carried out for vehicle design (Panerai F. et al., 2001; Burns P.C et al., 1999; Boer R. et al., 2001) and driver perception studies (Cavallo V. et al., 2001; Reymond G. et al., 2001).

Simulation fidelity and vestibular cues

A critical issue in driving simulation experiments and virtual testing is simulation fidelity. When driving tasks and handling are not in the focus of the experiments, relative perceptual fidelity, allowing relative comparison between the virtual and real conditions, might be acceptable. Training, driver station ergonomics and driver alertness or other human factors studies are examples of such relative fidelity simulation experiments. Absolute simulation fidelity may be needed on the contrary when human perception or handling is studied as a function of road, visibility vehicle or traffic conditions. In these latter cases, a careful analysis of the complete set of perceptual variables is necessary.

The type of equipment used in a given simulator configuration is then crucial. For example, speed perception was studied in foggy conditions, first with a limited field-of-view monitor, using reduced image contrast, showing increased drivers' speeds while driving (Snowden et al., 1998). Other studies with larger field-of-view driving simulators, using exponential

luminosity attenuation for fog rendering found, on the contrary, that driving speed was reduced accordingly to the fog density (Pretto et al., 2008). Furthermore, as Gibson has already pointed out, kinesthetic cues also strongly influence the perception of speed. Many other studies (Wierwille W.W. et al., 1983; Siegler et al., 2001) emphasized the importance of vestibular cues in driver perception of speed, acceleration or steering control.

Motion cueing can be produced using motion platforms. Traditional hexapod configurations, also known as Stewart platforms (Fig. 1) are composed of 6 hydraulic or electromechanical linear actuators. They generate angular accelerations in three rotational axes (roll, pitch and yaw) which can be used for the simulation of linear accelerations thanks to the principle of gravito-inertial equivalence. It can also generate linear motions along the x, y and z axes, but the duration of the generated vestibular (otholitic) stimuli are usually too low for a significant perception of braking or lane changes.
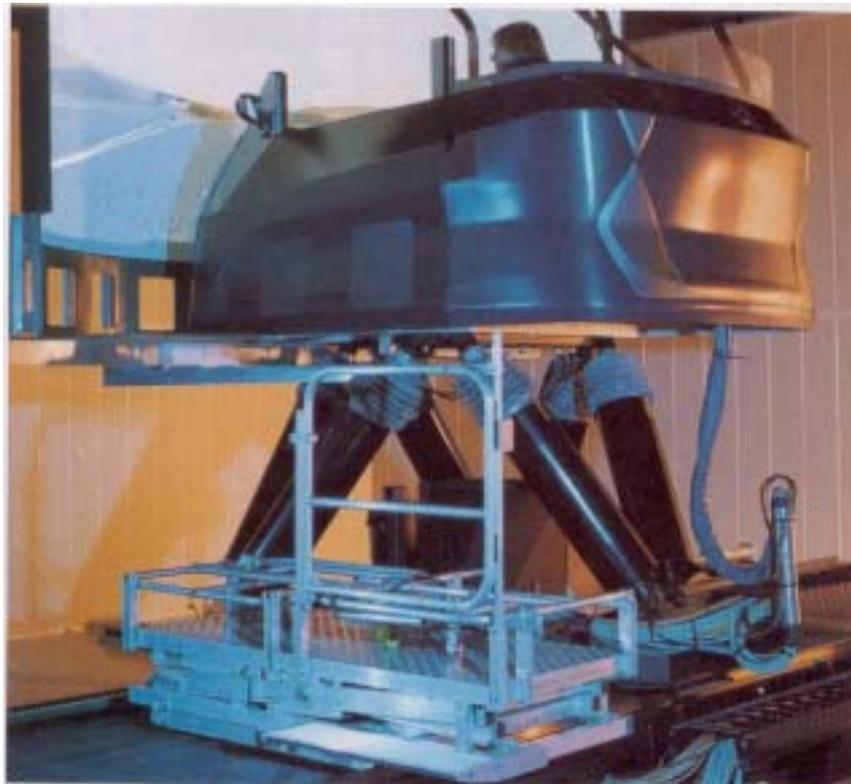

Figure 1. The high fidelity Ultimate driving simulator of Renault with a Stewart platform and additional X, Y linear actuators

High fidelity driving simulators use for this reason, additional large amplitude linear x, y actuators.

Visual cues

Driving simulators provide most but not all the visual information perceived by the driver during real driving. *Optic flow*, resulting from the continuous movement of the generated images of the scene, is present*, however*, *binocular cues*, as well as *motion parallax* information*, are generally absent in simulators. Stereoscopic view is usually not considered as essential for distance perception when observing distant objects in the scene, where other visual cues are also present (Von Hofsten, C., 1978). However motion parallax (Rogers, B. and Graham, M., 1979), the differential motion of point of points because of their different depths relative to the fixation point and to the motion of observer, provides robust estimates of absolute egocentric distances when combined with information about the observer's head movements.

Both stereoscopic and motion parallax information are often absent in driving simulators, except head mounted display equipped simulators, because of the cost and the complexity involved. However, even when motion parallax information is available, its proprioceptive integration with may reveal difficult to carry out with satisfactory *transport delays* in the different acquisition and rendering computation phases in order to avoid discrepancies between visual and vestibular information.

Virtual testing

Once the level of relative or absolute simulation fidelity is defined, driving simulator experiments can be carried out efficiently for vehicle design or perceptual studies. The use of driving simulators as virtual prototypes in comparison of physical prototypes may save significant cost and delay and enhance engineering design robustness. Virtual prototypes can be efficiently used for advanced vehicle design in the research phase or for vehicle synthesis in the vehicle engineering design phase and allow significant time and cost savings thanks to faster validation of vehicle systems.

The limits of the use of virtual prototypes lie in the validity of the used vehicle system modeling computer aided engineering tools, availability of vehicle or material data in the different domains of vehicle design engineering (vehicle behavior, acoustics, heating/cooling, consumption, reliability, vehicle architecture, on-board electronics and aerodynamics). Extensive vehicle measurement and simplified models may complete the usability of driving simulators as a virtual testing tool. Three examples of virtual prototypes, used at Renault, can illustrate virtual testing.

Headlight simulation

Headlight driving simulators are used at Renault since more than 10 years (Fig. 2.), based on the simulation of headlight illumination, thanks to supplier provided computational data (Lux). The simulator allows the validation of headlight design (Lecocq P. et al., 1999; Dumont et al., 2004) in driving conditions in a virtual test track environment (duplicated from

a real test track in Aubevoye, France), easy and fast headlight illumination characteristics modifications (pitch of lamps, light distribution and range, lighting in different weather conditions, etc.).

Figure 2. Headlight simulation in foggy conditions with Renault's headlight simulator

Vehicle architecture simulation

Vehicle architecture experiments are carried out at Renault since 5 to 6 years, using Renault's Augmented Reality (AR) simulator (Fig. 3). This simulator is allowing the comparison of CAD (Catia previously V4, presently V5) provided vehicle architecture data with real vehicle architecture as observed by the experimenters using AR Head Mounted Display (HMD) systems (Kemeny et al., 2008).

Figure 3. Renault's Augmented Reality (AR) simulator used for vehicle architecture studies

Simulation of driver aid and active safety systems

Driver aid and active safety systems, such as ABS, ESP, EPS, are the latest domains of virtual prototyping applications using high fidelity driving simulators equipped with large amplitude linear actuators or very large hexapod motion platforms (Chapron et al., 2008; Kemeny A., 2008). The limits of validation of the different tire, power train and vehicle suspension models, makes difficult a valid representation of the studied vehicle systems using driving simulation. Nevertheless, the use of scale factors, controlled experimentation scenarios and relative simulation validity makes possible to reduce significantly engineering design and specification validation and testing using driving simulators. If Renault is using since 3 years its Ultimate high performance driving simulator for active safety system validation (Fig. 1.), this domain is to be further developed in the next few years.

Conclusion

Driving simulation for virtual testing and perception studies becomes largely used, allowing efficient and fast vehicle engineering vehicle design and perceptual studies. Commercial off-the-shelf systems are already available and permit experimentations with relative simulation validity. Further future works will make possible the every day use of high fidelity driving simulators in the next years.

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