# Simulation and Perception

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## 1. Introduction

A driving simulator consists of a vehicle and an engine of sensory stimuli producing the virtual environment. This virtual environment acts onto the driver at both perceptional and cognitive levels. Perceptional cueing is mainly visual, auditory and kinesthetic. Cognitive processes allow the driver to better sense the environment, infrastructure (horizontal and vertical road signs) and traffic, by performing driving tasks using these information, both perceptional and cognitive.

Due to the human sensibility to cueing incoherence and sensory conflicts, especially regarding the perception of motion, it is essential to respect the characteristics of human perception systems. In the following, we shall review the influence of visual, vestibular, muscular and musculo-articular receptors on the characteristics of visual and kinesthetic rendering systems to take into account.

## 2. Visualization system

The human eye is an organ for perceiving visual features, providing information carried by light on the environment. The visual cueing system of a simulator stimulates partly the human visual perception by displaying images on a virtual screen. These images are computed in a viewing frustum defined by the field-of-view aperture and observation distance, then are displayed by an optical system and viewed by the observer.

*Space and time sampling*

Image generation, termed real-time, is done at frequencies and resolutions compatible with those of human vision. The chosen image frequency should guarantee a continuity in perception both in the frontal and peripheral fields, taking into account the persistency of vision. It should be set between 30 and 60 Hz for an acceptable visual comfort, depending on the applications. For instance, demanding users of train simulators may notice image doubling effects at 60 Hz, which makes the reading of signs impossible.
Moreover, in parallel with other more complex cues, such as *time-to-collision* [1], frequency indices play an important role in the perception of speed , especially in the peripheral field.

The availability of these information for observation depends however also on spatial frequency, and it is the combination of both resolutions, spatial and temporal, which define the overall display quality.

*Colorimetric and photometric resolution*

The resolution of the human eye is of 1 arc minute [2], depending however of the field-of-view and the spectral content of the perceived light. Perception of colors is better performed in the foveal area (dominant receptors: cones), whereas luminosity is better perceived in the peripheral area (dominant receptors: rods). In all cases, large field-of-view displays is compulsory for a sufficient immersion.

Respecting the driver vertical field-of-view may be however of an even higher functional importance, especially when driving heavy vehicles where it may reach 50° and more [3]. As a matter of fact, when the driver cannot see the virtual road close to the vehicle hood or bumpers, he is unable to recognize the position of his vehicle on the lane.

Renault-VI dynamic simulator, with 210°x50° field-of-view

Conventional simulators use video projectors, covering 50 to 60° each, which yields for a high-resolution display (1024x1280) around 3-4 arc minutes, but which may be improved by antialiasing techniques. These eliminates high frequencies in spatial resolution, and consequently improve visual comfort, but cannot compensate for the lack of information when viewing traffic signs for instance.

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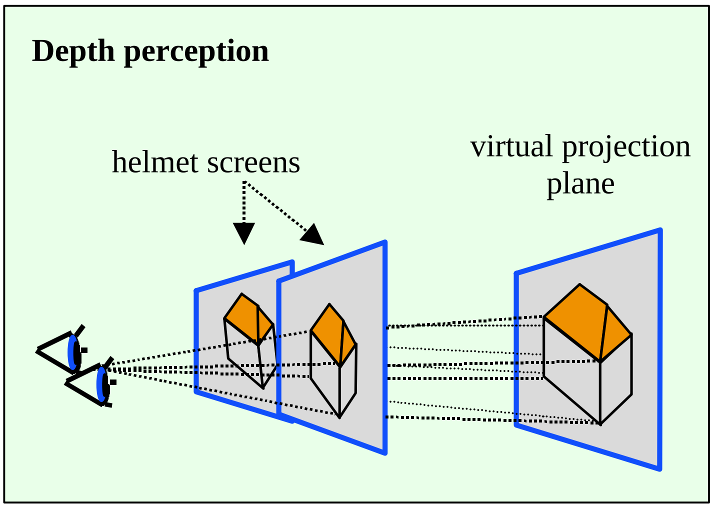
In order to better render colors, a good quality visual system computes color (first at polygon vertices describing the scene, then for all visible faces) on a least 24 bits, keeping other bitplanes for transparency, textures, etc. But the design of the geometrical database for the road scene and environment should be carried out at a sufficiently accurate level of detail, since the display, whatever its quality, will not create information that are not existing from the start.

Similarly, the colorimetric definition should take into account the scene as a whole, since the perceived color of an object varies with the characteristics of its close environment (a green color may appear yellow on a blue background – after Hunt 1977) [4].

*Depth cues*

For depth rendering, the visual software computes images based on linear perspective. However this information does not allow to perceive absolute distances [5], even when other depth indices are also used, such as textures. Binocular computation with a stereoscopic display yields absolute (vergence) and relative (disparity) depth cues, allowing a better perception of distances and volumes. In this case however, the system's collimation distance (virtual distance of convergence) or observation distance (accomodation) may cerate conflicts in visual cues.




Depth perception by stereoscopic vision

*Visual reflexes*

Several visual reflexes allow us to view a moving scenery (optokinetic nystagmus), moving objects (pursuit, saccade) or to keep our gaze in a fixed direction when moving the head (to anticipate for instance the future position of an object). The swiftness of this last reflex, named VOR (vestibulo-ocular reflex), is such that the coherence of visual perception in a visualization helmet requires a very short delay of the visual cueing system (position acquisition, image generation and display), less than 10 milliseconds if possible. This explain the difficulties encountered in their present use. This example shows the importance of visuo-vestibular coordination in simulation.

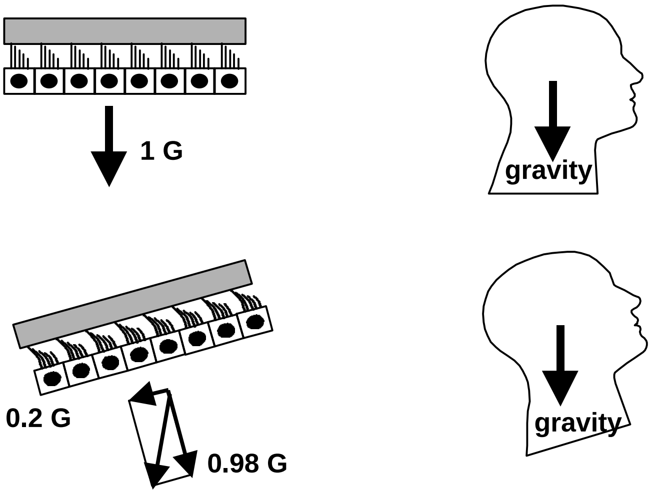
## 3. Motion cueing systems

For the perception of self-motion (proprioception) and gait control, man uses his muscular, musculo-articular and especially vestibular systems.

*Vestibular perception*

Inside the inner ear we have, close to the auditory system, vestibular organs (otoliths and semi-circular canals), responsible for the perception of linear and rotational motion.

The receptive cells in the otoliths allow, by the detection of their inclination, to measure linear accelerations. Because of the equivalence of gravity and linear accelerations, they can also measure head tilt. This fact is used by simulator motion platforms to render sensations of lateral and vestibular accelerations, as felt by the driver in curves, accelerations or braking [5].



Equivalence between gravity and linear accelerations

When setting the motion platform in a position suitable to render a sustained acceleration, the execution time should stay below a certain threshold, otherwise an opposite effect might be perceived. With a linear motion, for instance, a 0.01 G threshold is generally observed ; to detect it, the otolithic system would take more than 5 s [5]. Motion platforms used in many simulators [6,7,8] comprise 6 axes (and often of electromechanical technology) performing both linear and rotational motion. Limits in rotational displacement should be observed, because of induced perceptual effects, for instance high amplitude tilting produce a modification in the perceived horizon, on the side of motion between 20 and 60° (Müller effect) and in the opposite side between 70 and 90° approximately.

The 6-axes electromechanical motion platform in the TraCS truck driver training simulator.

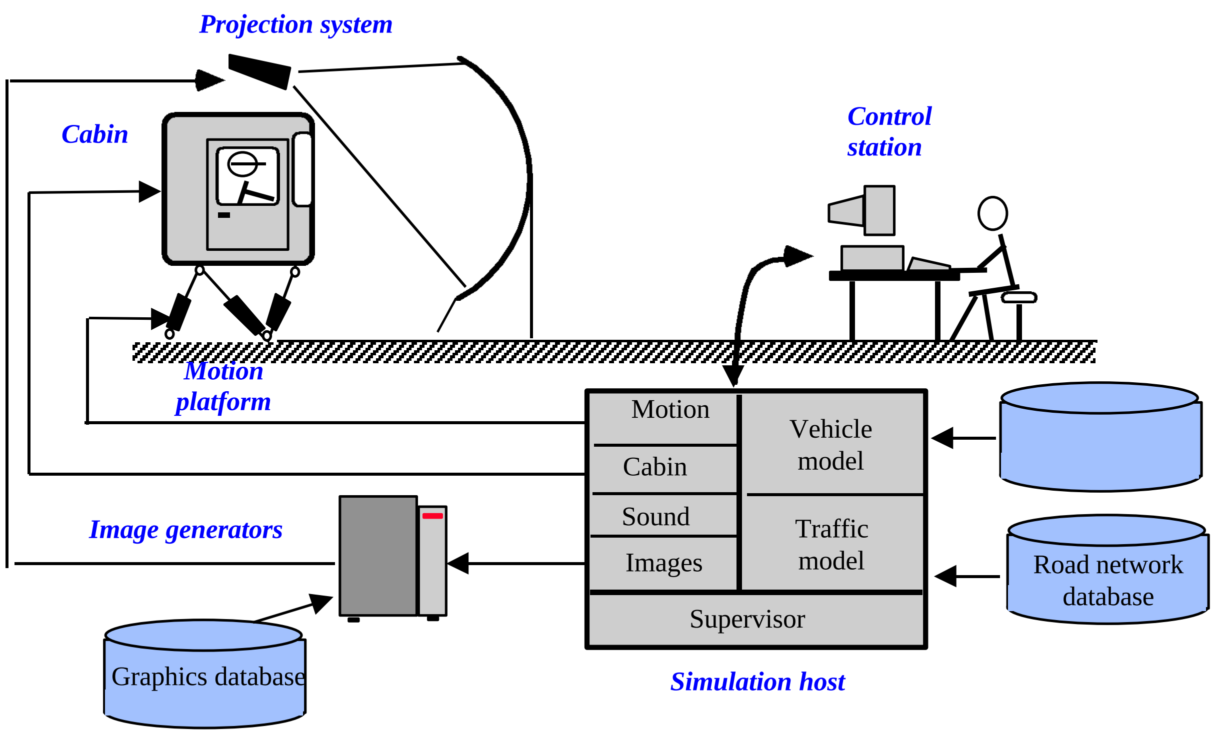
However, to render horizontal transient motion, linear actuators on rails must be used [9]. Moreover, with such platforms operating in the low frequency domain, additional platforms or vibration seats may be used, to render the vehicle road contact at 0-30 Hz frequencies.

## 4. Proprioceptive integration in motion rendering

Motion perception is stimulated both by the visual and motion rendering systems.

Tilting the driver cockpit should not induce a modification of visual references, such as the perceived horizon, so as not to produce visuo-vestibular conflicts. When the display system is not on-board for instance, a visual compensation should be done with a sufficient synchronization in order for the driver not to perceive discrepancies between visual and vestibular stimuli. It guarantees the stability of perceived horizon during motion with non-zero acceleration.

For motion perception, a crucial information is given by the steering wheel force feedback, perceived by human muscular and musculo-articular receptors. This kinesthetic feedback, perhaps the most important when driving a simulator, is difficult to render properly, mainly because of the transport delay of the whole simulation system.




Architecture of a dynamic simulator

*Transport delay*

The time elapsed between a driver's action and its result in the rendering of perceptional stimuli produces discomfort (simulator sickness) when too different from what is felt in a real vehicle. Recommendations form the Federal Aviation Administration for this factor in flight simulators [10] is 150-300 ms, but for vehicle driving simulators it is much lower, since the simulator is difficult to drive with transport delay greater than 50 ms [11]. This is essentially due to the nature of road contact producing variations in acceleration higher than with civil aircrafts.

Using stereoscopic visualization helmets requires even lower transport delays (cf. above), so as not to produce discomfort during head motion liked to the visuo-vestibular reflex. Accurate measurements on a simulator will be necessary to define the limits for retinal image stability during head movements with non-zero acceleration.

Image of road scene and cockpit, displayed in a visualization helmet

*Validation*

Although many studies [11,12,13] were carried out to characterize the quality in visual rendering in simulators, more studies are necessary to define the respective contribution of visual and vestibular stimuli to the perception of motion. These shall concern the measurement of sensory stimuli in driving tasks, such as speed or trajectory control. The role of cognitive information should not be forgotten in such case (influence of the traffic on speed perception for instance). A wide program which we will implement in the years to come.

## 5. References


1. Lee, D.N., 1976, A theory of visual control of braking based on information about time-to-collision, Perception, 5, pp.437-459

2. Kemeny, A. 1987, Synthèse d'images fixes et animées, Techniques de l'ingénieur, Paris, 1987, 5530, pp.1-21

3. Joubert, T., Kelada, J.M. and Kemeny, A., 1997, Display systems for truck training simulators, Proceedings of ITEC, Lausanne, April, 1997, pp.421-426

4. Viénot, F. 1999, Le modèle d'apparance colorée CIECAM 97s de la Commission internationale de l'éclairage, Objectifs et pratique, Séminaire Renault Synthèse d'image pour la simulation de conduite, Guyancourt, Juin, 1999, *In press*.

5. Boff, K.R. and Lincoln, J.E., 1988, The vestibular system in Engineering data Compendium: Human Perception and Performance, AAMRL, Wright-Patterson AFB, OH, 1988, pp.766-787

6. Nordmark, S., 1992, The new Trygg Hansa Truck Driving Simulator, Proceedings of AVEC, Yolohoma, Sep, 1992

7. Käding, W., 1994, The Daimler-Benz driving simulator, Proceeding of the RTS'94 Driving Simulation Conference, Paris, Jan., 1994, pp.94-106

8. Kelada, J.M., Kemeny, A. and Lailler, D., 1997, Scenario control tools for a dynamic truck simulator, Proceedings of the DSC'97, Lyons, Sep.1997, pp.215-226

9. Schill, V., Schmieder, H. and Gottlieb, W., 1997, Car research using virtual reality at Daimler-Benz, Proceedings of the DSC'97, Lyons, Sep.1997, pp.35-44

10. Federal Aviation Administration, 1991, Airplane simulator qualifications, Advisory Circular AC 120-40B

11. Bloche, Kemeny, A. and Reymond G., 1997, Transport delay analysis in driving simulators with head mounted displays, Proceedings of the DSC'97, France, Sep.1997, pp.85-98

12. Warner, H.D., Serfoss, G.L., Baruch, T.M. and Hubbard, D.C., 1993, Flight simulator induced sickness and visual displays evaluation, Final technical report AL/HR-TR-1993-0056, Brook AFB : Armstrong Laboratory, Air Force Material Command

13. Snowden, R.J., Stimpson, N., Ruddle, R.A., 1998, Speed perception fogs up as visibility drops. Nature 392:2, 450.