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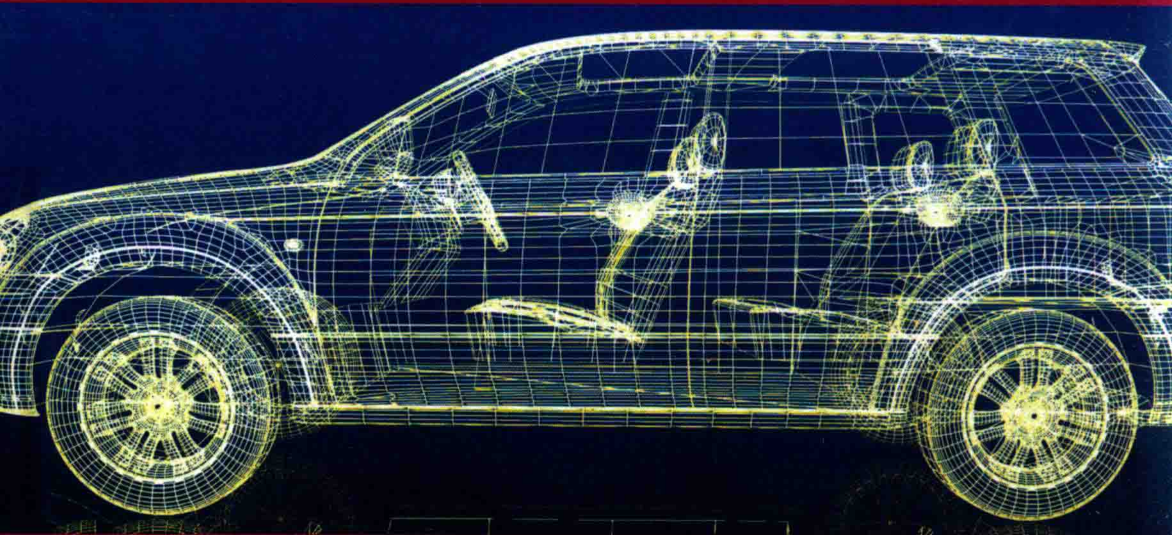

# Driving Simulation

Hichem Arioui and Lamri Nehaoua

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# Introduction

## I.1. Motorcycles versus Formation

Powered two-wheeled vehicles (PTWVs) are becoming an increasingly desirable traveling option, particularly due to their ability to avoid traffic congestion. However, PTWVs today remain a particularly dangerous means of transportation, which places their users at high risk.

The statistics of motorcycle accidents spanning over several years show that the users of two-wheeled motorized vehicles are among the most vulnerable in traffic: in France, there have been 1,000 – 1,600 deaths per year over the past 20 years, with an increase of 10% in 2009. According to the latest statistics, the number of fatalities amongst motorcyclists has decreased very slowly, whereas in the case of car drivers there has been significant progress. Consequently, the risk of being killed in an accident is 20 times higher for a motorcyclist than it is for a driver of a passenger car.

Several research groups have tackled this issue, having different objectives: (1) proposing several advanced rider assistance systems (ARAS) for new drivers and (2) implementing preventive aiding systems for motorcycle riders, which could improve the safety of motorcyclists before the dangerous situations actually occur. These dangerous situations may include poor assessment of turning speed, loss of control, excessive speed, loss of tire friction or skidding, and untimely braking.

These accident-prone factors are more or less frequent and/or serious, depending on the skill set of the riders. Over the past 5 years, the French National Interdepartmental Observatory on Road Safety has carried out a piece of research, revealing worrying statistics in terms of road traffic accident analysis on new riders. Every year, 680,000 people become "new drivers", on average. In 2009, 8.9% of the population were young people aged between 18 and 24 years old, and they represented 21.1% of deaths caused by road traffic accidents in the same year. On average, each week, 17 young people are killed and 264 are hurt, of which 149 are seriously injured. Young people aged between 18 and 24 years have a three times greater chance of being involved in a driving accident than people aged between 45 and 64 years. The accident of a young person costs the community, on average, 1,400,000 euros per death. What is more, the actions following obtaining a driving license, such as training courses or assessment meetings, have lowered the accident rate of new drivers by 7%.

The decrease in the accident rate of two-wheeled vehicle riders is, however, very small compared to that of other road users. Although there are several reasons for explaining this, we can perceive two main reasons:

– The offer of training courses for motorcycle driving is very poor and not very diverse. A large number of accidents are directly due to the fact that riders are not aware of the risks incurred by certain driving situations and the dramatic consequences that they can cause in terms of injuries.

– There is an increased delay in terms of ARAS in relation to the advancements that we notice in passenger cars. At this point, there are less than 10 pieces of safety technology per motorcycle. There are, however, several intelligent transportation systems (ITS) for other vehicles that could be extended to two-wheeled vehicles. However, this latter point is beyond the scope of this book.

The lack of training can be compensated for by diversifying motorcycle driving tests, by confronting, for example, the motorcyclist with several more or less dangerous driving situations. These scenarios will improve the reflex of the rider and, consequently, their experience. Unfortunately, it is very difficult, and even dangerous, for beginners to try to predict these scenarios during their tests or in their exam periods. Implementing a training and awareness-raising tool for riders, thus allowing research to be carried out on their behavior in the middle of road traffic, is therefore a major challenge in terms of road safety.

## I.2. Motorcycle road accident analysis

PTWVs are an increasingly desirable means of transportation, particularly due to their ability to avoid traffic congestion. Despite a general drop in the accident rate, PTWVs remain a particularly dangerous means of transportation, which makes their users highly vulnerable. In France, the number of PTWV riders who are victims of accidents represents more than 23% of the total deaths (15% for all of Europe) and 40% of the total number injured (statistics given in 2010 by the French National Interdepartmental Observatory on Road Safety), taking into consideration that these vehicles represent 1.5% of the total road traffic, in terms of the number of kilometers covered, according to the same report. The chance of being killed is thus 14 people per 100 million persons-kilometers, or 21 times higher than in a car. Moreover, the chance of becoming the victim of serious injuries that will later cause a disability is also 50 times higher.

Despite the awareness-raising campaigns and the measures that have been taken over the past few years, the situation of the PTWV continues to worsen. In 2009, in fact, we saw an increase in fatal accidents in France (+10%), despite the fact that at the same time the number of people killed in traffic accidents had decreased by 4%. These alarming statistics prove the need for research on the origin of this kind of lack of safety. Indeed, we must consider that the PTWV is a special category among road vehicles, characterized by a specific, dynamic behavior, which is constantly on the brink of instability. Their gauge and performances bring about specific interaction difficulties with the other road users. In the following, we will present an non-exhaustive list of the main factors involved in the PTWV accidents:

– The infrastructure: this is a determining factor in the riding process and the accident rate of PTWVs, even more than with cars. This type of vehicle only uses two wheels for ensuring contact with the road; the tire friction must be optimal in order to ensure good balance in riding conditions and in emergency situations. The environment constitutes for 8% of the accidents involving PTWVs.

– Taking a turn: the motorcyclist is particularly vulnerable when on a curve because he or she needs to tilt the vehicle so as to oppose centrifugal forces. This tilting of the motorcycle increases the chances of skidding, particularly if combined with a worn rubber lining. This factor alone is responsible for 57% of motoring accidents.

– Intersections: the problem is mainly related to low visibility caused by a variety obstacles (billboards, trees, etc.), or other vehicles. This risk is responsible for about 38% of the accidents occurring at intersections, or a mortality rate of 2.5.

– Urban areas: these constitute the greatest part of accidents that involve two-wheeled vehicles. Indeed, the design of urban road infrastructures, with broad visual perspectives, large and multiple lanes, encourages overtaking and lane shifting. It also contributes to choosing direct trajectories and to maintaining a high speed in these areas that are potential sources of conflict.

– Traffic circles: these encourage high-speed riding. Problems connected to the visibility on PTWVs may occur in traffic circles, especially when combined with an entry angle that is too low.

– The friction of the road: a two-wheeled vehicle can easily lose control by a simple change in the surface of the road. Such a change compresses and quickly decompresses the suspensions, which reduces the friction between the tire and the road. Other elements such as speed inhibitors, speed bumps and road markings can also cause a loss of adherence, particularly at high speed.

– Speed limit and accident rate: even if there has been a decline in the accident rate since 2005, exceeding the speed limit is extremely common behavior on the road. All networks considered, more than 40% of automobile drivers, 50% of truck drivers and 60% of motorcyclists are affected by it.

# Contents

# 1

# Driving Simulation

## 1.1. Objectives of driving simulation

When driving a vehicle (either a four-wheeled or a two-wheeled vehicle), there are a variety of sources of information that enable the driver to follow a given lane and to control their vehicle. The objective of a driving simulation is therefore to provide the illusion of self-movement via a virtual vehicle, in accordance with real-time information, excluding control blocks (such as a motorcycle's handlebars, accelerator and braking system). This illusion is a complex phenomenon that involves the proprioceptive sensors of the human being, especially the visual, kinesthetic and vestibular systems.

Designing a driving simulator is a compromise between how faithful the perceptual representation will be and the global cost of the proposed architecture. While the design of automobile simulators is a highly active field of research, motorcycle driving simulation remains in its infancy, there being very few prototypes in the world. Because of balance issues, the problem of immersion is even more complex for a two-wheeled vehicle rider.

A driving simulator is a tool that recreates, in an artificial context, the driving situation of a vehicle. The number of simulator users has been ever increasing. However, depending on their needs and the respective discipline, their requirements in terms of performance and simulation realism are different. Thus, the primary objective of vehicle manufacturers is to test the vehicle–driver interaction in order to assess its impact on new driving devices being integrated in the vehicle and the reaction of these devices to different operations performed by the driver. Nowadays, technological innovations considerably alter the driving of the real vehicle. The new advanced driver assistance systems (ARAS), such as electronic stability program (ESP), information systems such as global positioning system (GPS), and finally X-by Wire systems – all make driving a very different task from what it used to be several years ago. Therefore, before incorporating a system into a real vehicle, the vehicle manufacturers are obliged to carry out tests in order to make sure the system makes a positive contribution to the driving process. It is therefore important to have rapid prototyping systems in order to optimize the duration of the development phase on the one hand, and to predict and correct the problems that may arise when driving the real vehicle on the other hand. Vehicular driving simulators are the ideal tools for implementing such tests.

Although this objective can never be fully achieved, manufacturers try to faithfully reproduce, on the simulator, the environment that the driver will face in real life. Their objective is to enable the driver to experience the majority of the sensations perceived in a real vehicle. Thus, the simulator cabin is generally based on the cockpit of a real vehicle. Devices with effort feedback or haptic feedback are coupled with certain piloting tools, such as the steering wheel and the pedals (brake and clutch), so as to provide the driver with a haptic simulation, similar to the one they would experience in a real vehicle. One or several screens reproduce the virtual scene, most often covering a broad visibility for the driver. An audio feedback simulating the traffic, the engine speed, the noise of the wind, as well as other indicators of the speed of the vehicle are also rendered in 3D. The mobile platforms are considered to be one of the most important elements that can improve the realism of the simulation. They are meant to replicate, as faithfully as possible given the working space of the platform, the inertial effects of the simulated vehicle. Therefore, they enable the drivers to better perceive the dynamic of the vehicle (i.e. the inertial effects) and, consequently, to exert better control over the vehicle.

## 1.2. A short history of driving simulators

Driving a vehicle requires that different elementary tasks are fulfilled in order to place the vehicle on a particular trajectory or take it to the desired state. It is therefore necessary to have information regarding the different states of the vehicle. This information is acquired by multiple human sensory receptors, and is then combined and merged together in order to interpret and analyze the current driving conditions and come up with appropriate decisions.

Starting from this discussion, we can understand that the multiplication of informational feedback is very important for creating an acceptable illusion. During the design phase, it is necessary to consider the different characteristics of the perceptual systems for recreating a coherent virtual environment and to study the different compromises for reducing sensory conflicts and trying to protect the user from simulator sickness.

According to the literature, there are about a hundred simulators in the world. Whether they are academic, industrial or commercial, several institutions have started to build their own prototypes for different aims. Generally, the simulators are classified depending on their mechanical architecture, which, on its own, gives us a rough idea of the complexity and the objectives pursued.

### 1.2.1. *Fixed-base platforms*

Fixed-base platforms do not have any mechanical movement. The inertial indicators and other dynamic effects are absent and, consequently, no motion reproduction technique is used. The motion sensation is exclusively induced by the convection caused by visual feedback. These simulators are made of an instrumented cabin, and besides the visual projection they are also sometimes equipped with an