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Human Integration in Simulation

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Abstract

In this paper we discuss the effectiveness of "immersing" a human-in-the-loop virtual realistic simulation process. Simulations are a vital part in the design process where the designer can optimize the characteristics of a product before they are fabricated. The vehicle driving simulator is taken as the illustration of the need for considering the human interface of a simulator that emulates performance of automotive mechatronics systems. Issues and use of human immersion in evaluating the simulated products are discussed.

Keywords Simulation, Human Interface, Vehicle Dynamics.

1 Introduction

It is important to understand and design the interface between the designer and the simulator carefully, in order to extract the necessary information from the model. It is this interface that often lacks the attention of the the engineer.

If a system concept has been carefully modeled and validated, the results of the simulation will be an accurate representation of the physical performance. However, these results will only be useful if they help the engineer to relate variations in inputs or parameters to the output behavior. In other words, simulation of system performance should offer an intuitive understanding of the system's characteristics.

Figure 1 shows the essential processes in a typical product research and development. To shorten the lengthy process of research and development, computer-aided engineering design and analysis tools are often employed. Use of computer simulation has been demonstrated to be an effective tool in the systems engineering process of the product R&D.

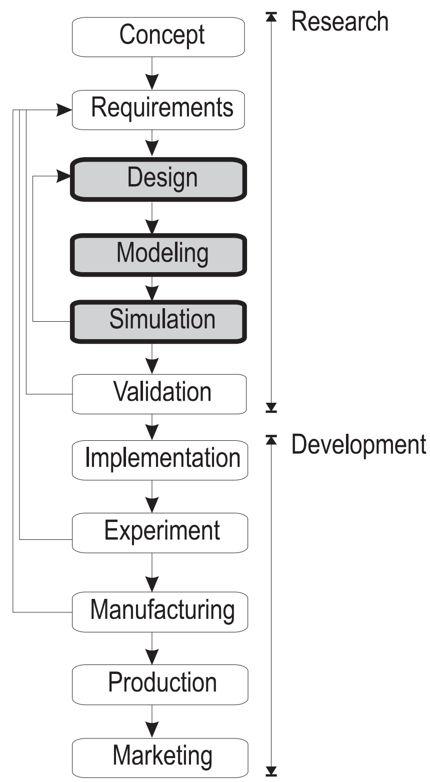

Figure 1: Typical Basic Stages in R&D of a Product.

The important difference between the experimental prototyping design methods and the computer based design process, is that much of the experimental testing and benchmarking is replaced by simulation. Simulation of a system enables the engineer/designer to understand the behavior of the system and its components, and serves to help validate the performance of the designed system.

Crucial for successful simulation is the interface between the design engineer and the simulator. The level at which the engineer can "communic-

Figure 2: Picture of the immersive driver cab.

ate" with the design in the computer environment, is the level at wich the simulation approaches the experimental testing in the conventional development process. For instance, if the engineer would like to observe the top-view of the system during a typical manuever, he should be able to in the simulation.

2 Automobile Driving Simulator (ADS)

This paper discusses the role of man-machine interaction in evaluating automotive mechatronics systems through the use of an automobile driving simulator. Figure 2 shows the setup for a driver's cab for operating a virtual automobile, while the functional subsystems for the hybrid virtual driving simulator is shown in Figure 3.

The simulation of accurate vehicle dynamics opens a world of opportunities to test and learn in a way that would be too dangerous in real practice. A human driver can take place behind the steering wheel as if he is driving a real vehicle, and handle it without concerning dangerous and costly accidents. Think of educating drivers how to use ABS, and how not to. Or how to maneuver the vehicle in skid situations, in snow or on wet road surface. The simulator is thus a good instruction tool to teach people their driving skills.

Besides the educational effect there's also the marketing issue. A simulation of rapid manouvring, aided by advanced vehicle stability control systems, can turn into a selling demonstration of stability control products. The customer can take a ride in a vehicle that is equipped with the stability control system, and virtually try every road and weather condition.

Here we will focus on the design and development process of automotive systems where the vehicle simulator is of use. Application examples are ABS, traction control, cruise control, driving stability, active suspension, yaw-rate stability and so forth. The R&D for many of these applications is expensive in terms of money, facilities and time. Especially the efforts for prototyping and experimentation require time from people and test facilities.

In simulation of a virtual realistic prototype, much of the time consuming experimentation and debugging can be done at desktop level. In such a simulation, the dynamic behavior of the vehicle is animated by computing the dynamics and rendering a graphical composition of the vehicle and the virtual environment in real time. The designer has control over the vehicle by means of a driver cab, consisting of a steering wheel, throttle, break and can see the world through the windshield in 3D by means of stereoscopic vision.

The user is immersed inside the full-vehicle simulation through actuation of a shaker-table on which the driver cab is mounted. This system generates the forces that a human driver would experience if the real vehicle would be driven in an experimental test drive.

The objective is to generate a perceptually reliable representation of a real-world system. It must allow engineers to efficiently implement prototypes of advanced automotive subsystems in order to study their behavior and the effects of them on the total vehicle performance.

3 Components and Applications of the ADS

The components of the ADS may consist of:

1. Hardware Prototyping & Virtual Prototyping of Mechatronics Functions. Actual hardware prototyping mechatronics components such

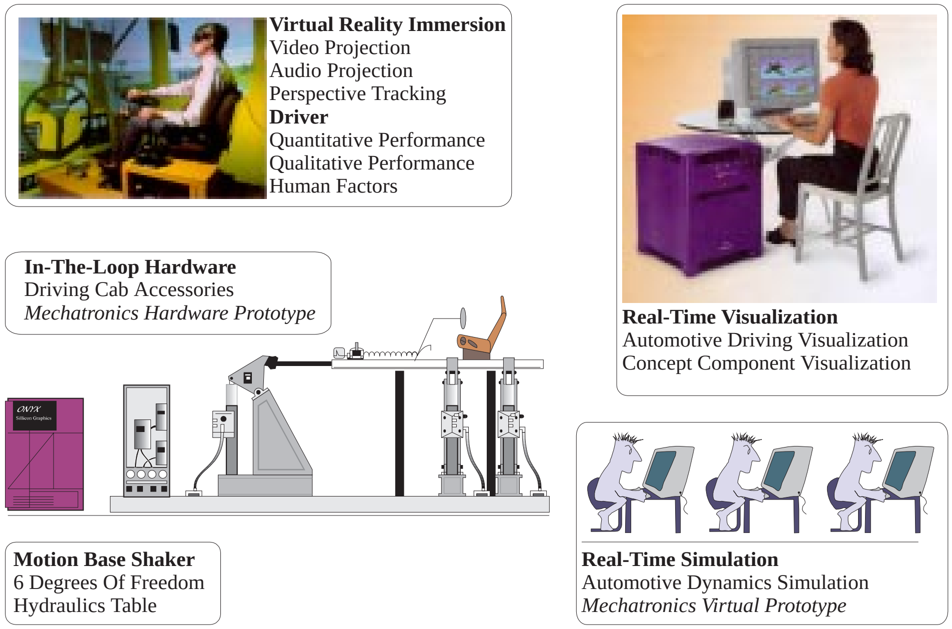

Figure 3: The hardware setup for the total immersion vehicle driving simulator.

as embedded micro-controller modules, electronics circuits, electromechanical devices and so on, can be incorporated as hardware-in-the-loop simulation. Where this is not desirable or possible, virtual software prototyping of the functions will be employed. The functions of these prototypes must be carefully validated.

2. Virtual Prototypes of Mockup. The mock-up involves graphical rendering of the shapes, sizes and colors of the mechatronics objects being developed as well as the driving scenery and enviromnent. It includes the capability to animate these objects with respect to the dynamical functions of the prototypes.

3. Virtual Realistic Immersion. To provide a virtual realistic immersion of a human subject, the driving simulation must operate in real time to react to the inputs from the subject. It must then provide the visual, audio, motion and force-feedback responses to the subject.

These considerations for the ADS will provide a virtual test-bed that can "predict" performance of the automotive product in the following ways:

Functional Design How it works (behavioral performance, component optimization) and how it reacts and interacts with user and environment.

Object Design How it fits (mechanical CAD, Object collision) and how it looks (shapes, color, size)

Human factors How it feels and operates, and how a used likes it after evaluating it in the virtual driving environment and scenarios.

With these capabilities, the ADS can be employed to study concepts, implement preliminary design and analyze feasibility of new automotive mechatronics systems. It can replicate existing driving environments and scenarios as well as create new what-if driving circumstances and situations. The products that are being considered for evaluation include: *Handling & Comfort Mechatronics Product* such as Anti-Lock Brake System, Traction Control System, Steering Stability System, Active Suspension System and Anti-Roll Suspension System; *Mobility Concepts* such as Power-train & Running gears; *Emission and Fuel Economy Study* such as Hybrid Electric Vehicle; *Active Safety Concepts* such as Collision Avoidance System, Lane Departure Detection System, Adaptive Cruise Control, Detection of Drowsy Driver; and Other Technologies such as Drive by Wire Systems for steering, speed control, brakes. Other applications of the ADS may include driver education and training for military, police and emergency related personnel.

A man-machine interface thus enables a human to "live" inside the simulation world of a representation of the designed system. The experience of immersion relates proportionally to the detail and completeness of the interface. For example, noises, natural force and motion feedback, even smell are usually ignored, but of great importance to emulate a realistic experience.

A vision-only prototype of the simulator has been developed for ITT Automotive. This system has been setup for demonstration during the 1997 SAE Congress Exhibition in Detroit. The video demonstration will give an impression of the immersive effect of the simulator.

4 Human Immersion

Issues for immersing human in the ADS that are being addressed include real-time clock for the simulation and for the interface response, and the washout effect.

4.1 Real-Time Clock

The foremost important requirement for realistic perception in human immersive perception is timing. People cannot "scale" time. They cannot imagine a system for real, when its characteristic behavior does not compare with a realistic system behavior.

For example in the case of the vehicle dynamics simulator, any driver will try to speed up, until the graphical perception of the simulator output "looks and feels" like 60 mph. For an extremely fast simulator, this may in actuality be a very low velocity, so that the dynamic character is very rigid and stiff. Or in contrary, when the simulator is relatively slow, the driver may actually be driving 200 mph, which *looks like* 60 mph, which will make the virtual vehicle extremely difficult to handle.

4.2 Real-Time Response

The second important timing issue relates to the reactivity of the peripherals. Eventhough the reaction time of a human is minimal 400 msec, the interface should show zero delay, in order for the user to appreciate a realistic simulation. We expect a visual and sensual reaction of the system that relates to our own reaction time. This means that there is no room for timely processing in transferring peripheral data to the simulation.

When the behavior of the actual system is characterized by a time delay, it will have to be incorporated in the system model. The phylosophy is that the interface simulates a real-world physical relation. It is not part of the model, and has no memory or states.

In order to account for the critical realistic timing, the simulation is extracted from the miscellaneous sub-tasks, and implemented in a digital signal processing board. It communicates through a high speed communication bus with different CPU's that execute the subsequent interfacing processes. Figure 4 shows the experimental setup of the system. The graphics animation is serviced by an SGI hardware rendering machine, and the peripherals are interfaced by a dedicated CPU.

4.3 Washout Effect

Human sensory system has a means of conjuring up the same motion sensation even though the dynamical forces and accelerations in a ADS are not absolutely identical to the actual field motion. This perceptual phenomena are being studied and will be utilized to compensate for the limitation of the ADS when it comes to replicating more severe or fuller motion in a vehicle study.

5 Conclusion

The virtual vehicle simulation system is operative and has proven to be a successfull testbed to study a variety of driving manouvers. The hardware configuration as explained in Figure 4 allows for unlimited addition of vehicle control subsystems and peripherals, without influencing the critical realistic timing of the simulator.

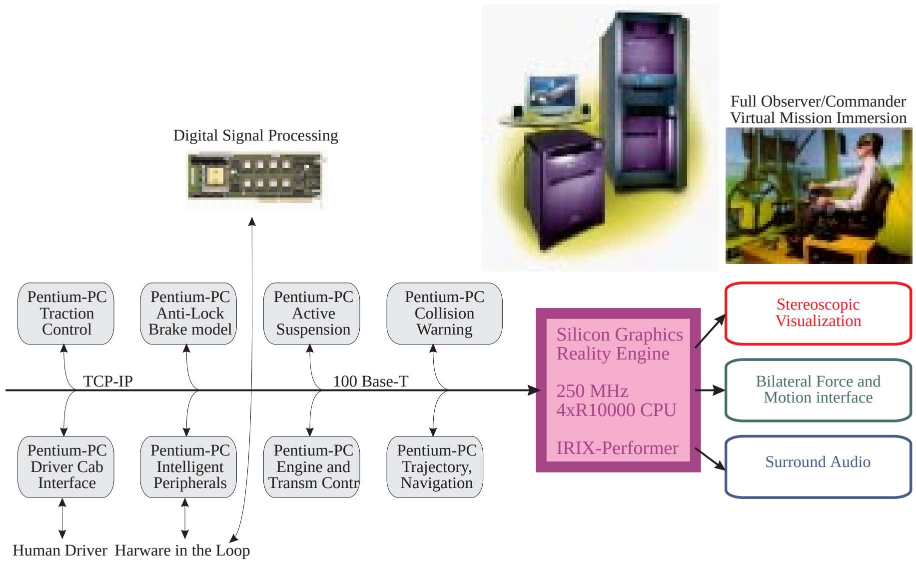

Figure 4: The vehicle simulator consists of a bus structure with multiple CPU's that collectively render the human immersion and vehicle dynamic behavior in real time.

Developing virtual realistic driving simulation is a continuous learning curve, that teaches more than anything about the freedom and constraints of human perceptual immersion in simulation. The emphasis made here is that timing is most critical and can be handled best by separating essential tasks into stand-alone processes on different CPU's.

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