From Driving Simulation to Virtual Reality

Dr. Andras Kemeny

Center for Virtual Reality and Immersive Simulation, Renault

Institut Image, Arts et Métiers ParisTech

andras.kemeny@ensam.eu

ABSTRACT

Driving simulation from the very beginning of the advent of VR technology uses the very same technology for visualization and similar technology for head movement tracking and high end 3D vision. They also share the same or similar difficulties in rendering movements of the observer in the virtual environments. The visual-vestibular conflict, due to the discrepancies perceived by the human visual and vestibular systems, induce the so-called simulation sickness, when driving or displacing using a control device (ex. Joystick). Another cause for simulation sickness is the transport delay, the delay between the action and the corresponding rendering cues.

Another similarity between driving simulation and VR is need for correct scale 1:1 perception. Correct perception of speed and acceleration in driving simulation is crucial for automotive experiments for Advances Driver Aid System (ADAS) as vehicle behavior has to be simulated correctly and anywhere where the correct mental workload is an issue as real immersion and driver attention is depending on it. Correct perception of distances and object size is crucial using HMDs or CAVEs, especially as their use is frequently involving digital mockup validation for design, architecture or interior and exterior lighting.

Today, the advents of high resolution 4K digital display technology allows near eye resolution stereoscopic 3D walls and integrate them in high performance CAVEs. High performance CAVEs now can be used for vehicle ergonomics, styling, interior lighting and perceived quality. The first CAVE in France, built in 2001 at Arts et Metiers ParisTech, is a 4 sided CAVE with a modifiable geometry with now traditional display technology. The latest one is Renault's 70M 3D pixel 5 sides CAVE with 4K x 4K walls and floor and with a cluster of 20 PCs. Another equipment recently designed at Renault is the motion based CARDS driving simulator with CAVE like 4 sides display system providing full 3D immersion for the driver.

The separation between driving simulation and digital mockup design review is now fading though different uses will require different simulation configurations.

New application domains, such as automotive AR design, will bring combined features of VR and driving simulation technics, including CAVE like display system equipped driving simulators.

Keywords

Driving simulation, Virtual reality, CAVE, Scale 1:1 perception, Augmented Reality, Simulation sickness, Transport Delay

1. INTRODUCTION

Driving simulation and Virtual Reality (VR) are closely connected from the very beginning. Their history starts for both in the 1960-s and very quickly they are using both *computer generated imagery* (CGI), are *interactive* with *sensory feedback* and provide physical and mental *immersion* for an efficient use [1].

Driving simulation starts in the 1960s. Doron Electronics Inc., founded in 1970, acquires the driving simulation business from the Singer Company and becomes the first company to develop and produce complete driving simulation systems [2]. The early versions nevertheless do not use computer graphics imagery (CGI), only film based display systems. If the first real time CGI system from General Electric is ready in the early 1960s, it is displaying only a couple of dozen non-textured polygons [3]. We have to wait until the 1970s to see the development and use of the first motion based driving simulator with CGI at VTI and the first full scale motion based driving simulator at Daimler in the late 1980s [4], [5], [6].

In the meantime, if the term of Virtual Reality was coined by Jaron Lanier only in 1987, the first Head Monted Display (HMD) for Virtual and Augmented Reality is built in 1968; even though it could display then only wired frame images [7]. The first CAVE installations arrive in the early 1990s [8], [9]. In France, the 1st CAVE is installed at Institut Image of Arts et Métiers ParisTech in Châlon-sur Saône in 2001. In the same time HMD based or head slaved display equipped driving simulator are installed at BMW, TNO, Renault and Volvo [10], [6], which show already the close relationship between the fields of driving simulators and VR. CARDS, a Comprehensive Automotive R&D Simulator, motion based and equipped with a large field of view (FOV) HMD, is developed in 1999 in the framework of a European Eureka project, in collaboration between Renault, the French

Laval Virtual VRIC'14, April 9-11, 2014, Laval, France.

national research organization CNRS, the British SEOS and the Swedish Clarus[1] among others.

Figure 1. HMD equipped motion based simulator prototyping, CARDS © Renault

Even the corresponding technical centers of the largest French automotive companies follow this movement; first the Technical Center for Simulation at Renault, now renamed Center for Virtual Reality and Immersive Simulation and the Driving Simulation and Virtual Reality Department at PSA Peugeot Citroën, managing installations, development and use of driving simulators, CAVE and other immersive devices.

2. PERCEPTION OF MOVEMENT

If driving simulation and VR are using the same technics they share the same or similar difficulties in rendering movements of the observer in the virtual environments, at low speed in CAVEs and at higher speeds in driving simulators The worst case is when the observer/driver is turning while driving or moving using a control device (ex. Joystick) in a CAVE or in a static driving simulator. This is due to the *visuo-vestibular conflict*, due to the discrepancies perceived by the human visual and vestibular systems induce the so-called *simulation sickness* [11] as the observer/driver may see rotations not perceived by the inner ears.

Another cause is the *transport delay*, the delay between the action and the corresponding rendering cues.

[1] Clarus was founded by Dan Lejerskar and Stefan Hallin in 1977 in Goteborg, Sweden. Stefan Hallin was the CEO of Clarus, later CEO of Opticore. Dan Lejerskar was CEO of Prosolvia AB and founded EON Reality in Irvine, CA, based on Clarus EON ™ software, trademark of Prosolvia AB. Eon Reality announced on December 10, 2014 EON Reality to establish subsidiary and open an edutainment and training hub in Laval, France. Stefan Hallin was previously head of VR group at Volvo and has built the first HMD based driving simulator in Sweden in the mid-1990s.

This transport delay depends on the acquisition of observer/driver actions and movements (especially head movements), image frequency rate and motion rendering and may create strong perceptual discrepancies [12]. When observing an image computed in function of head movements, small delays may induce nausea as the Vestibular Ocular Reflex (VOR), which is responsible of eye fixations, is very quick, about 20ms [13]. When driving, these effects may be smaller than for passengers or passive observers as the efferent copies of information given by steering wheel, pedals or other control devices help the driver to anticipate the movement [14].

To avoid simulation sickness transport delay should be limited to 50 ms in driving simulation [15], 20 ms using HMDs and CAVEs or head slaved or HMD based driving simulators because of the rapidity of the VOR reflex.

Other factors may play a role, as expectations based on previous experiences [16] or any other physiological parameters which influences postural stability. One way to deal with simulation sickness is to provide an acceptable face value of motion, for example by reducing sensory conflicts generating generic proprioceptive cues. For driving simulator experiments where rendering vehicle behavior is essential nevertheless high fidelity motion restitution is necessary and a scale 1 simulation of acceleration may be needed [17].

3. PERCEPTION OF DISTANCE, SPEED AND ACCELERATION AT SCALE 1:1

Absolute validity of driver simulation is not always required as often, for human factors studies; only the comparison of the studied man-machine interface or traffic situation is needed, requiring only relative validity of the simulated driver-vehicle situations [18]. Correct perception of speed and acceleration in driving simulation is crucial for automotive experiments for Advances Driver Aid System (ADAS) experiments as vehicle behavior has to be simulated correctly and anywhere where the correct mental workload is an issue as real immersion and driver attention is depending on it [19].

Speed perception is depending on the visual field of view, in part because of the role of peripheral field of view in motion perception by the human visual system and partly because of the corresponding generated immersion level and probably on other parameters, such as steering wheel force feedback and overall CGI quality [20]. The correct perception of accelerations requires the use of motion platform [21], which makes driving in a CAVE difficult, especially with rear projection floor, allowing only limited payload.

Correct perception of distances and object size is also crucial using HMDs or CAVEs (Figure 2), especially as their use is frequently involving digital mockup validation for design, architecture or interior and exterior lighting. Early VR validation studies showed already differences in distance and scale 1:1 perception between VR and real life conditions [22].

One of the most important visual depth cues is motion parallax and its role was shown real, virtual environments [23], [24], [25]. Nevertheless, the precise role of binocular convergence [26], [27] and cognitive factors [28] are still to be further clarified both for scale 1:1 and distance perception.

Figure 2. Digital Mockup Design Review validity evaluation

4. APPLICATIONS

In the early years of driving simulation, most of the use-cases were concerning human factors [29] and driver training [30], though already ADAS simulation experiments were also carried out for preliminary engineering design [31]. Nevertheless an effective use for man-machine interface design was limited by the display system resolution, mostly limited to 2,5 to 3,0 arc min resolution [32] and even less, about 4,0 arc min in CAVEs [33], compared to the human eye approximately 1 arc min resolution [34].

These limitations in visual spatial resolution limited also the use CAVEs in the automotive area to mostly vehicle architecture (visibility), habitability and virtual mock-up assembly early design studies [35]. As in a CAVE motion is limited, applications are more oriented to interactions with the interior and exterior of a car. Limitations in visual and haptic resolution made until recently the HMDs as an acceptable alternative [27].

Today, the advents of high resolution 4K digital display technology allows near eye resolution stereoscopic 3D walls and integrate them in high performance CAVEs. High performance CAVEs now can be used for vehicle ergonomics, styling, interior lighting and perceived quality [36].

Figure 3. Renault's 70 M 3D pixels 5 – sided high performance CAVE™

One of the new application domains for both driving simulators and CAVEs, including CAVE like display system equipped driving simulators (Renault has recently invested in the upgrade of its motion based CARDS driving simulator with CAVE like display system with approximately 2 arc min resolution) is Augmented Reality (AR) vehicle equipment. Early design experimentations have already been carried out in the 1990s [37], [38] for Head Up Display (HUD) systems. Extended HUD and AR systems now can be experimented in driving simulator and CAVE experiments.

Figure 4. Virtual view of Guyancourt, rendered with OpenSD2S

Convergence between driving simulation and VR technologies can also be observed in the recent evolution of driving simulation software (SCANeR © Studio, OpenSD2S) which integrate now virtual cockpit and stereoscopic view [39] as well as of high end visualization software tools (DeltaGen from RTT Dassault Systems) which integrates a real driving module with IPG's Carmaker vehicle dynamics solution. Along with those applications high quality finger tracking technics shall also be integrated for complete virtual immersion both for driving simulation and virtual reality systems [40]. A number of CAVEs are already equipped with a removable driver stations for ergonomics or vehicle architecture applications in ecological driving situations (Figure 5.).

Figure 5. Renault's high performance CAVE™ with driver station

5. CONCLUSION

Driving simulation from the very beginning of the advent of VR technology uses the very same technology for visualization and more and more for tracking and high end 3D vision. The separation between driving simulation and digital mockup design review is fading even if different uses will require different simulation configurations. New application domains, such as automotive AR design, will bring combined features of VR and driving simulation technics.

REFERENCES

[1] Shermann W. R., Craig A. B. 2003

Understanding Virtual Reality, Morgan Kaufmann, San Francisco.

[2] Allen R. W., Rosenthal T. J., Cook M. L. 2011

A short history of driving simulators, In Handbook of driving simulation for Engineering, Medicine and Psychology, Fisher D. L., Rizzo M., Caird J. K., Lee J. D., Boca Raton, FL:CRC/Press Taylor and Francis, Ch. 2, pp. 2.1 – 2.16.

[3] Kemeny A. 1987

Synthèse d'images fixes et animées. Techniques de l'ingénieur, E 5 530, pp. 1-21.

[4] Drosdol J., Panik F. 1985

The Daimler-Benz driving simulator, a tool for vehicle development, SAE paper, n° 850334.

[5] Nordmark S. 1994

Driving simulators, Trends and Experiences, Proceedings of the Driving Simulation Conference, Real Time Systems, Paris, January 1994, pp.5-13.

[6] Kemeny A. 2000

Simulation and Perception of Movement ,Proceedings of the Driving Simulation Conference, Paris, pp.13-22.

[7] Sutherland I. E. 1968

A Head-mounted Three Dimensional Display, FJCC Thompson Books, Washington, D.C., pp.757-764.

[8] Carolina Cruz-Neira, Daniel J. Sandin, Thomas A. DeFanti, Robert V. Kenyon and John C. Hart 1992

The CAVE: Audio Visual Experience Automatic Virtual Environment, Communications of the ACM, vol. 35(6), 1992, pp. 64–72.

[9] Carolina Cruz-Neira, Daniel J. Sandin and Thomas A. DeFanti 1993

Surround-Screen Projection-based Virtual Reality: The Design and Implementation of the CAVE, SIGGRAPH'93: Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques, pp. 135–142.

[10] Kappé B., Erp J. B. F., Korteling J. E. 1999

Effects of Head-Slaved and Peripheral Displays on Lane-Keeping Performance and Spatial Orientation, Human Factors; 41, pp. 453-46.

[11] Kennedy, R. S., Lane, N. E., Grizzard, M. C., Stanney, K. M., Kingdon, K., & Lanham, S. 2001

Use of a motion history questionnaire to predict simulator sickness, Proceedings of the Sixth Driving Simulation Conference -DSC2001, France, pp. 79-89.

[12] Berthoz A. 2002

The Brain's Sense of Movement, Harvard University Press.

[13] Kemeny A. 2001

Recent developments in visuo-vestibular restitution of self-motion in driving simulation , Proceedings of the Driving Simulation Conference, Sophia Antipolis, September 2001, pp.15-18.

[14] Dagdelen M., Reymond G., Kemeny A. 2002

Analysis of the visual compensation in the Renault driving Simulator, Proceedings of the Driving Simulation Conference, Paris, pp 109-119.

[15] Allen R. W., Jex H. R. 1980

Driving simulation, mechanization and application, SAE paper, n° 800448.

[16] Reason J. T., Brand J. 1975

Motion Sickness, London: Academic Press.

[17] Zeeb E. 2010

Daimler's New Full-Scale, High-dynamic Driving Simulator – A Technical Overview, in Trends in Driving Simulation Design and Experiments, Proceedings of the Driving Simulation Europe Conference, Paris, pp. 157-165.

[18] Kemeny A. 2009

Driving simulation for virtual testing and perception studies, Proceedings of the Driving Simulation Conference Europe 2009, Sophia Monte Carlo, pp.15-23.

[19] Barthou A., Kemeny A., Reymond G., Merienne F., Berthoz A. 2010

Driver trust and reliance on a navigation system: effect of graphical display, In A. Kemeny, F. Mérienne, S. Espié (Eds.), Trends in Driving Simulation Design and Experiments. Les Collections de l'INRETS, pp. 199-208.

[20] Panerai F., Droulez J., Kelada J-M., Kemeny A., Balligand E., Favre B. 2001

Speed and safety distance control in truck driving:comparison of simulation and real-world environment, Proceedings of the Driving Simulation Conference, Sophia Antipolis, pp.21-32.

[21] Siegler I., Reymond G., Kemeny A., Berthoz A. 2001

Sensorimotor integration in a driving simulator: contributions of motion cueing in elementary driving tasks, Proceedings of the Driving Simulation Conference, Sophia Antipolis, pp.21-32.

[22] Loomis, J. M. and Knapp, J. M. 2003

Visual perception of egocentric distance in real and virtual environments, In Virtual and Adaptive Environments, eds. L.J. Hettinger and M. W. Haas, Erlbaum, Mahwah NJ., pp. 21-46.

[23] Rogers B., Graham M. 1979

Motion parallax as an independent cue for depth perception, Perception 8, pp. 125-134.

[24] Panerai, F., Cornilleau-Peres, V. and Droulez, J. (2002)

Contribution of extraretinal signals to the scaling of object distance during self motion, Percept Psychophys. 64, pp.717-731.

[25] Kemeny, A. and Panerai, F. 2003

Evaluating perception in driving simulation experiments, Trends Cogn Sci. 7, pp. 31-37.

[26] Paillé D., Kemeny A., Berthoz A. 2005

Stereoscopic Stimuli are not used in Absolute Distance Evaluation to Proximal Objects in Multi-Cue Virtual Environment., Proceedings of SPIE Vol. 5664, pp.596-605.

[27] Kemeny A., Combe E., Posselt J. 2008

Perception of Size in Vehicle Architecture Studies, Proceedings of the 5th Intuition International Conference, Torino, Italy.

[28] Glennerster A., Tcheang L., Gilson S. J., Fitzgibbon A. W., Parker A. J. 2006

Humans ignore motion and stereo cues in favor of a fictional stable world, Current Biology 16(4), pp. 428-432.

[29] Stein C., Allen R. W., Rosenthal T. J., Parseghian Z. 1995

Applications of Low-Cost Driving Simulation, Proceedings of the Driving Simulation Conference, Sophia-Antipolis, pp. 422-435.

[30] Flippo A. 2000

Trust, the truck simulator for training, Proceedings of the Driving Simulation Conference, Paris, pp. 293-302.

[31] Bernasch J., Haenel S. 1995

The BMW driving simulator used for the development of a driver-biased Adaptive Cruise Control, Proceedings of the Driving Simulation Conference, Sophia-Antipolis, pp. 158-174.

[32] Jamson A. H. 2000

Driving Simulation Validity, Proceedings of the Driving Simulation Conference, Paris, pp. 57-64.

[33] Brooks F.P. 1999

What's real about virtual reality? Computer Graphics and Applications, IEEE, Vol. 19, 6, pp. 16-27.

[34] Wheeler P. 2009

High definition cinematography, Focal Press, Oxford.

[35] Voillequin T. 2006

First steps of Haptics at PSA Peugeot Citroën, Special session of industrial applications of force feed-back, VRIC’06, LAVAL.

[36] George P., Kemeny A., Merienne F., Chardonnet J.R., Thouvenin I. M., Posselt J., Icart E. 2013

Nomad devices for interactions in immersive virtual environments, Proc. SPIE 8649, The Engineering Reality of Virtual Reality 2013.

[37] Kemeny A. 1993

Cooperative Driving, in Advanced Technology for Road Transport: IVHS and ATT. Ian Catling, Artech House, pp. 196-209.

[38] Servignat C., Flores J. L., Kemeny A., Vernet M. 1995

The role of a driving simulator in an ergonomics evaluation procedure: the case of an on-board aid system, Proceedings of the Driving Simulation Conference, Sophia-Antipolis, pp. 78-93.

[39] George P., Kemeny A., Guo C., Merienne F., Wang F., Joubert T. 2013

OpenSD2S: New features and perspectives for an Open-Source Driving Simulation software, The Proceedings of the Interservice/Industry Training, Simulation & Education Conference (I/ITSEC), Vol. 2013.

[40] Gosselin F., Jouan, T. Brisset, J. Andriot, C. 2005

Design of a wearable haptic interface for precise finger interactions in large virtual environments, Proceeding of the First Joint Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, pp. 202 - 207