HapSeat: A Novel Approach to Simulate Motion in a Consumer Environment

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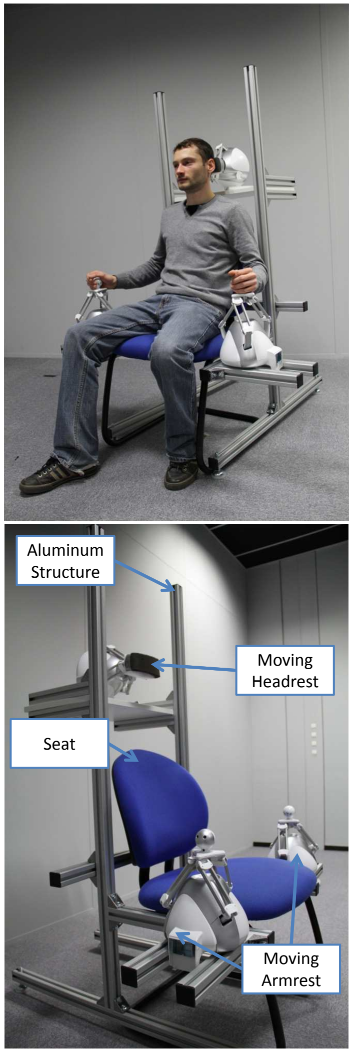

Figure 1: Prototype of the HapSeat.

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Abstract
The *HapSeat* is a novel approach for simulating motion sensations in a consumer environment. Multiple force-feedbacks are applied to the seated users body to generate a 6DoF sensation of motion while experiencing passive navigation. A set of force-feedback devices such as mobile armrests or headrests are arranged around a seat so that they can apply forces to the user. Several video sequences have been created to highlight the capabilities of the *HapSeat*. We propose to CHI attendees to experience these videos enhanced by haptic effects of motion.

Author Keywords
sensation of motion; force-feedback; haptic seat; audiovisual experience

ACM Classification Keywords
H5.2 [**Information interfaces and presentation**]: User Interfaces. - Haptic I/O.

Toward motion simulation in consumer environment
Motion simulators are well-known devices designed to make the user feel motion. They are intensively used in driving or flight simulators for training purposes. Most are based on a Stewart platform, a 6 Degrees of Freedom

Figure 2: Screenshots of the videos (from top to bottom): Horse Riding, Rollercoaster, Spaceship and 4D Home Cinema.

(DoF) platform driven by 6 hydraulic cylinders [4] (see [8] for a typical example of a Stewart platform-based driving simulator). This technology, mainly used in virtual reality settings, is coming to entertainment applications through video games, amusement parks and "4D cinemas". Besides, recent results show that haptics has a great potential for enhancing video viewing experience [1, 6]. We believe that the next step of this evolution would be the use of motion simulators in consumer environment. Though Stewart platform-based motion platforms provide a realistic sensation of motion they remain expensive for mass market and they are not suitable for consumer settings. Simpler setups based on force-feedback [7, 2] or vibrating devices [9] would be more adapted but they trigger only a limited sensation at the moment.

Then to fill the gap between these two categories we propose the *HapSeat* [3]. Instead of moving the whole user's body as on motion platforms, only some parts of the body are stimulated. The perception of motion results from the stimulation of various parts of the body: vestibular system, visceral organs, kinesthetic system (see [5]). Our approach is built on the hypothesis that local forces can generate a global sensation of motion (see [2, 3] for practical validations). A prototype has been created, relying on three low-cost actuators held by an armchair-shaped structure. Two of them stimulate the user's hands while a third one stimulates the head (see Figure 1).

The HapSeat demonstration

We propose to the CHI audience to discover this new type of motion simulator. The user comfortably seated on the *HapSeat* will experience videos enhanced with haptic effects of motion (see Figure 3). In order to illustrate the capabilities of the HapSeat we propose 4 sequences (see Figure 2). The duration of each sequence is around one minute.

The Horse Riding - A camera coupled to an inertial measurement unit (IMU) has been fixed on a horse rider's torso. This results in a first person point-of-view video of a horse riding session. Thanks to the data from the IMU, the rider's movements are rendered on the *HapSeat*. The user will feel as he is riding an actual horse!

The Rollercoaster - With this sequence the user will enjoy the exciting sensations of a rollercoaster. The *HapSeat* will provide realistic vibrations and motion effects.

The Spaceship - The user will board a virtual spaceship navigating among the galaxy. This sequence aims to show a 6DoF movements rendered by the *HapSeat*.

The 4D Home Cinema - This last scenario aims to show the capabilities of the *HapSeat* to enhance a classical movie. Various haptic effects are rendered all along a movie (vibrations, force-feedback, motion).

Technical Description

The novelty of this work lies on: (1) a novel approach for motion simulation replacing expensive motion platforms by multiple low-cost force-feedback, (2) the design of a new device, and (3) the development of a workflow including a new control algorithm.

Device

An aluminum structure was designed to allow the positioning of the three actuators around an ordinary chair. The user passively rests his or her head and hands on each of the 3DoF actuators while watching a projection on a screen positioned in front of the chair (see

Figure 3: The user, comfortably installed on our device, is experiencing passive navigation enhanced by a haptic effect of motion.

Figure 3). The head actuator is equipped with a block of foam to ensure user's comfort.

Our current prototype uses three Novint Falcons[1] actuators. These commercial devices are robust, relatively cheap and the forces generated seem appropriate for safe movement of the users head and hands.

Workflow

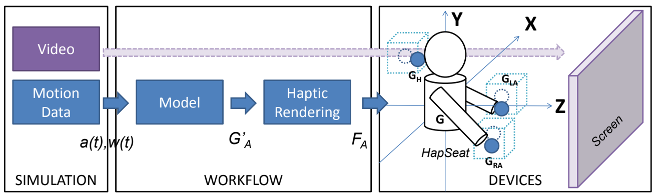

Figure 4: Workflow overview. Motion data, describing the movement in the video, are used by the model to drive the rendering device.

Motion Data. The input of our system is audiovisual content augmented with data describing the motion in terms of linear acceleration $a(t)$ and angular velocity $w(t)$. This kind of content can be easily produced by a video camera equipped with an inertial measurement unit (see [2]). This setup has been used for the Horse Riding scenario. A 3D simulator may also be used: audiovisual content is recorded by a virtual camera and motion data generated by the physics engine (Spaceship scenario). Finally these data may be manually edited and added to an existing video (Rollercoaster and 4D Home Cinema scenarios).

Model for motion rendering. Motion data are used to drive the *HapSeat* while audiovisual content is played. The following model is used to compute the ideal position of the actuator A at each instant t (see [3] for more details).

$$\overrightarrow{G_A G'_A} = f(\begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & s_z \end{bmatrix} a(t),$$
$$(R_x(m_x w_x(t)) R_y(m_y w_y(t)) R_z(m_z w_z(t)) - I_3)\overrightarrow{GG_A}) \quad (1)$$

with

$$f(\vec{B}, \vec{C}) = \frac{\|\vec{B}\|\vec{B} + \|\vec{C}\|\vec{C}}{\|\vec{B}\| + \|\vec{C}\|} \quad (2)$$

where G is the center of the coordinate system, G_A is the position of the actuator A at rest and G'_A the target position. R_x, R_y and R_z are the 3D rotation matrices around their respective X, Y and Z axes and I_3 is the identity matrix of R^3. s_x, s_y, s_z and m_x, m_y, m_z are different scaling factors to map the actual motion represented by the couple ($a(t)$, $w(t)$) in the workspace of the actuator.

Haptic Rendering. The force to be rendered by the actuator is computed by a spring-damper model:

$$F_A = k(G'_A - P_A) - dV_A \quad (3)$$

G'_A is the targeted position (from Equation 1), P_A the current position of the actuator, V_A its velocity, k the spring constant and d the damping constant.

Haptic-audiovisual player. This rendering algorithm was integrated to a home-made multimedia player that allows

[1] http://www.novint.com

the haptic rendering to be synchronized with the audiovisual playback. The haptic loop runs at 1KHz on an ordinary computer. The value of the force of each actuator is updated at each instant t.

Results and Perspectives

A user study has been conducted to evaluate the quality of the simulated movement and its impact on the quality of the video viewing experience [3]. The device was also tested by 100 people during several internal events. Participants reported that the simulated motion was consistent with their real-world experience and they experienced a sensation of self-motion. In general we observed that quality of experience is increased by the *HapSeat* and we received enthusiastic and positive feedback from the audience.

This new way of simulating motion in a consumer environment opens the path to novel immersive applications. The prototype is not limited to motion simulation but can also provide force-feedback and vibration effects which enable even more creative possibilities. Furthermore the input capabilities of the actuators could be used to allow the user to interact with the simulation, offering the prospect of extending applications of the *HapSeat* to flight or driving simulators, teleoperation and more!

References

[1] Alexander, J., Marshall, M. T., and Subramanian, S. Adding haptic feedback to mobile tv. In *ACM CHI EA* (2011), 1975–1980.

[2] Danieau, F., Fleureau, J., Cabec, A., Kerbiriou, P., Guillotel, P., Mollet, N., Christie, M., and Lécuyer, A. A framework for enhancing video viewing experience with haptic effects of motion. In *IEEE Haptics Symposium* (2012), 541–546.

[3] Danieau, F., Fleureau, J., Guillotel, P., Mollet, N., Christie, M., and Lécuyer, A. HapSeat: Producing Motion Sensation with Multiple Force-feedback Devices Embedded in a Seat. In *ACM VRST* (2012), 69–76.

[4] Dasgupta, B. The Stewart platform manipulator: a review. *Mechanism and Machine Theory 35*, 1 (2000), 15–40.

[5] Harris, L. R., Jenkin, M. R., Zikovitz, D., Redlick, F., Jaekl, P., Jasiobedzka, U. T., Jenkin, H. L., and Allison, R. S. Simulating self-motion I: cues for the perception of motion. *Virtual Reality 6*, 2 (2002), 75–85.

[6] Israr, A., and Poupyrev, I. Tactile brush: drawing on skin with a tactile grid display. In *CHI 2011*, ACM (2011), 2019–2028.

[7] Lécuyer, A., Vidal, M., Joly, O., Mégard, C., and Berthoz, A. Can haptic feedback improve the perception of self-motion in virtual reality? In *IEEE HAPTICS* (2004), 208–215.

[8] Lee, W., Kim, J., and Cho, J. A driving simulator as a virtual reality tool. In *IEEE Robotics and Automation* (1998), 71–76.

[9] Riecke, B. E., Schulte-Pelkum, J., Caniard, F., and Bülthoff, H. H. Towards lean and elegant self-motion simulation in virtual reality. In *Virtual Reality* (2005), 131–138.