PhD thesis

e107, Monday 14 November 2011 - 16:19:17

» Y. Visell, *Walking in virtual worlds: Physics, perception, and interface design*. McGill University, Dept. of Electrical and Computer Engineering, 2011.

The sensorimotor capacities of the foot are crucial to human locomotion in diverse environments, to gathering information about walking surfaces, and to interacting with objects on the ground. Locomotion is increasingly employed to allow users to control and navigate within immersive virtual environments, but, in contrast to the hand, little attention has been given to the rendering of haptic sensations for the feet. This thesis addresses several challenges motivated by the problem of realizing haptic experiences of walking on virtual ground surfaces. First, a novel family of interfaces is introduced, based on a vibrotactile display integrated in a rigid floor plate. Its structural dynamics and controller have been optimized to ensure its ability to accurately reproduce mechanical vibrations over a wide frequency band, which was instrumental to realizing the perceptual study presented in the second part of the thesis. Distributed arrays of these devices are used to simulate virtual ground surfaces and floor-based multi-touch surfaces, whose usability for human-computer interaction is empirically demonstrated. The second component of this thesis is an experimental study of the contribution of vibrotactile sensory information to the perception of ground surface compliance. A novel haptic perceptual illusion is demonstrated, in which the apparent compliance of a floor surface is increased by vibrations felt via the plantar sole of the foot. This investigation also revealed the surprising ability of the vibrotactile floor interface to overcome, in part, a core limitation: its inability to display kinesthetic force-displacement information. The third part of the thesis analyzes texture-like mechanical signals produced through inelastic physical processes in complex, disordered materials like those encountered during walking in many natural terrains. Patterns of fluctuations accompanying sliding friction and fracture processes in quasi-brittle, heterogeneous materials subjected to time-varying loads are characterized using methods from statistical physics. This analysis was used to formulate novel algorithms for the haptic synthesis of high-frequency signatures of fracture processes in fiber composites and compressed granular media. In conclusion, this thesis presents an innovative hardware interface and techniques for interacting with virtual ground surfaces. It also demonstrates a new haptic perceptual effect that lends justification to the display paradigm adopted here. Finally, it analyzes and models transient, texture-like physical phenomena associated with stepping onto complex, natural ground materials.