A Vibrotactile Device for Display of Virtual Ground Materials in Walking

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. We present a floor tile designed to provide the impression of walking on di erent ground materials, such as gravel, carpet, or stone. The device uses a ordable and commercially available vibrotactile actuators and force sensors, and as such might one day be cost-e ectively used in everyday environments. The control software is based on a lumped

. 1. Left: An image of the tile prototype, showing the tile surface (polycarbonate sheet), vibrotactile actuator, force-sensing resistors, structural frame, and associated electronics. Right: Diagram of the same, including the PC running the floor material simulation.

or irregular surfaces) during locomotion. However, such devices have characteristically provided an unfamiliar and compliant surface feel. Our tiles are meant to provide a simpler and lower-cost alternative to haptic locomotion devices, and perhaps to furnish information complementary to what they o er.

To date, less e ort has been dedicated to representing the rich array of material textures that are explored via the feet during walking, despite the fact that aesthetically and informatively designed ground materials have long played a role in urban environments, parks, and buildings. A second motivation for the approach described here is that the tiles concerned may one day be seamlessly and cost-e ectively applied in such contexts.

Our work draws on physically based sound synthesis models of contact interactions between the feet and the floor [2,3]. Due to the common physical origin of the stimuli, such models can also be used to generate vibrotactile cues. Haptic rendering methods for simulation of low-level physical phenomena, such as impacts, friction, or rolling, have more commonly been applied to manual interaction with virtual environments (as overviewed in [5]).

Identification of Ground Materials in Walking. The feet may be seen as well suited to the display of ground textures, because of the high density of tactile mechanoreceptors in the soles. However, whether people are able to use such tactile information to identify the materials they are walking on is less obvious. This question motivated recent experiments carried out by the authors [4] to measure subjects' abilities to perform such identification tasks, and to assess subjects' use of haptic, proprioceptive, and auditory information in ground material identification. The materials included both solids (e.g. marble) and aggregates (e.g. gravel or sand). Subjects were able to discriminate between very similar materials (such as gravels of similar coarseness) at highly significant levels, by walking on them. Prior research has explored how material properties of objects are perceived from their acoustic signatures when struck [9]. Lederman and her colleagues have studied how well t

2 Device Design and Methodology

The current device design (Figure 1) consists of $12 \times 12 \times 0.5$ inch polycarbonate tile a xed to dense foam supported by a structural frame. A powerful linear mo-

resistor data was subsequently calibrated using a laboratory scale, providing force data with an accuracy of approximately +/- 10 Newtons respectively for toe and heel. A similar calibration has been performed with the sensors of the tile itself.

2.2 Model Parameter Identification: Aggregates

The identification of synthesis model parameters from this data is ongoing work, but we describe it briefly here. For aggregate interactions, the most salient parameters are the modal frequencies and decay times of the material and the force-to-impact event rate correspondence. The same procedure can be used for

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