Capturing Rich Auditory-Haptic Contact Data for Surface Recognition

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I. Motivation

The sophistication of biological sensing and transduction processes during finger-surface and tool-surface interaction is remarkable, enabling humans to perform ubiquitous tasks such as discriminating and manipulating surfaces. Capturing and processing these rich contact-elicited signals during surface exploration with similar success is an important challenge for artificial systems. Prior research introduced sophisticated mobile surface-sensing systems [1]–[3], but it remains less clear what quality, resolution and acuity of sensor data are necessary to perform human tasks with the same efficiency and accuracy. In order to address this gap in our understanding about artificial surface perception, we have designed a novel auditory-haptic test bed. This study aims to inspire new designs for artificial sensing tools in human-machine and robotic applications.

II. Auditory-Haptic Sensing

Our test bed consists of an optical motion-capture system (Vicon, Vantage 5), miniature high-bandwidth accelerometers (STMicroelectronics, IIS3DWB), a high-fidelity microphone (Brüel and Kjaer, 4955), and a six-axis force/torque sensor (ATI Industrial Automation Inc., Nano43) to capture relevant auditory and haptic data from contact interactions (Fig. 1(a)). As a prerequisite for our computational analysis, we are able to include the tool-tip position, tool-tip speed, tool orientation, contact sound, tactile vibrations at two locations (tool and finger), and contact force during surface exploration (see Fig. 1(d)).

For this study, we selected a diverse set of nine surface textures (Fig. 1(c)) inspired by prior surface datasets [1]–[3]. In addition, we considered three hemispherical steel tools with thermally hardened tool tips (Fig. 1(b)). During data acquisition, each of the two experimenters recorded rich intra-class surface data by varying their speed and applied normal force. The users were asked to choose a free but circular motion in order to capture rich signals from different contact conditions and phenomena.

III. Ongoing Data Analysis

We are currently analyzing and evaluating the acquired surface data. In this process, we are leveraging ideas from recognizing surfaces with kernel mean embeddings [4] to elucidate the configuration of sensor information and resolution that are necessary for highly accurate surface recognition. By leveraging modern machine-learning techniques, we believe auditory and haptic time series can be used more efficiently for surface perception in the absence of any visual information, thereby enabling industrial applications in manufacturing, material processing, and inspection.

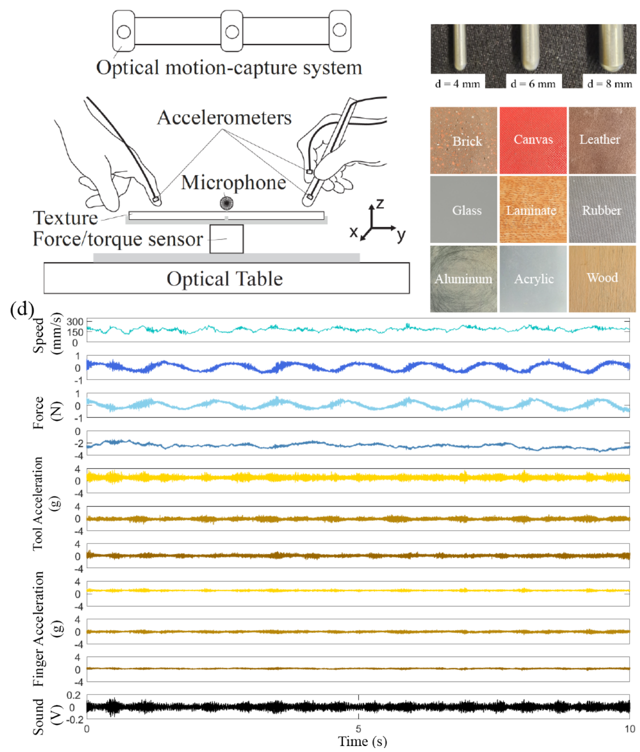

Fig. 1. (a) Test bed. (b) Three steel tools with different diameters. (c) Set of nine diverse surfaces. (d) Sample tool-surface recording.

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