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A mechatronic platform for human touch studies

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ABSTRACT

The development of a mechatronic tactile stimulation platform for touch studies is presented. The platform was developed for stimulation of the fingertip using textured surfaces, providing repeatable tangential sliding motion of stimuli with controlled indentation force. Particular requirements were addressed to make the platform suitable for neurophysiological studies in humans with particular reference to electrophysiological measurements, but allowing a variety of other studies too, such as psychophysical, tribological and artificial touch ones. The design of the mechatronic tactile stimulator is detailed, as well as the performance in tracking reference trajectories. Using microneurography, we recorded from human tactile afferents and validated the platform compatibility with the exacting demands of electrophysiological methods, comprising the absence of spurious vibrations and the lack of relevant electromagnetic interference.

1. Introduction

To study neuronal mechanisms of the sense of touch in the human hand, active or passive protocols are used. In active touch the subjects are asked to explore tactile stimuli [1], while in passive studies tactile stimuli are presented to the fingertip, which is kept still [2]. The exploration or presentation of stimuli should be replicated several times in the same conditions to infer models based on statistical analysis of acquired data [3]. To achieve standardization and repeatability, the passive touch approach requires a robotic stimulator that enables detailed analyses of receptor response or Central Nervous System (CNS) processing through controlled variation of stimulation parameters, of stimulus materials, spatial coarseness and tribological properties, to make comparisons between sessions or participants, or to average over a large number of replications. As regards the neurophysiologic experimental paradigms, in the periphery the activity of single afferents in the skin can be recorded using the microneurography technique [4]; CNS activity can be probed using electroencephalography (EEG) to reconstruct cortical sources [5], while sensory thresholds and percepts can be assessed using psychophysical methods [6].

This study presents the development of a 2 DoFs mechatronic system that could indent and slide textured stimuli to the fingerpad with feedback-controlled normal contact force and parametric sliding trajectories while recording the normal and tangential forces at finger-stimulus interface. The robotic system has been devised with an open design approach since it is simple to command via a graphical user interface, is upgradable thanks to the FPGA control electronics, and can be used to perform neurophysiological studies in humans with techniques such as microneurography and EEG [7] even in combination with psychophysical experimental paradigms. Also, it is suitable for tribological and artificial touch studies as well and it allows to implement a wide variety of protocols for active [8] and passive studies [9].

There are a number of particular requirements in the design of such a robotic device. First, to allow repeatable experiments with standardized conditions, accuracy and precision in the control of stimulation parameters, such as the contact force and the sliding velocity profile, is required. Second, the device must guarantee a range of forces and movement velocities covering those that would be used by humans in the exploration of textures, while both normal and tangential forces need to be recorded as they are fundamental for human touch investigation. Studies on discriminative touch [10,11] suggested: for the indentation force a range of at least 100 mN–5 N, with a control accuracy of about 5% of the reference force and sensing resolution within a few mN; 100 mm of stroke along the sliding direction and velocities up to 150 mm/s with μm position sensing resolution and steady state control accu-

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