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The TouchBox: open-source haptic device for finger-based interaction

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The TouchBox is a low-cost DIY human-computer interface providing fast, wide-band and high-dynamics vibrotactile feedback, tracking the position of up to two finger-pads in contact with its top surface, and measuring their contact areas as well as the applied normal and lateral (3D) forces. Finger-pressing is a common gesture while interacting with everyday objects, including digital devices. Also, while one or more fingers are in contact with an object (as the result of finger-pressing), another common gesture is that of pushing or sliding the finger(s) over the touched surface, giving rise to shear strain. The proposed interface addresses a simplified version of such scenario. Applications range from using the interface as calibrated measurement device to advanced human-machine interaction.

The TouchBox is conceived as an open hardware/software project (CC BY-SA 4.0): An open-access data repository¹ linked to GitHub stores DIY instructions, mechanical and electronic specifications and schematics, 3D models, software for analyzing sensors data, and for generating interactive vibrotactile and auditory feedback.

A former version of the device – measuring only normal force and contact area of a single finger – was recently used in a psychophysical experiment that tested vibrotactile sensitivity thresholds under active touch conditions, bringing results of high interest for the design of haptic interfaces [2].

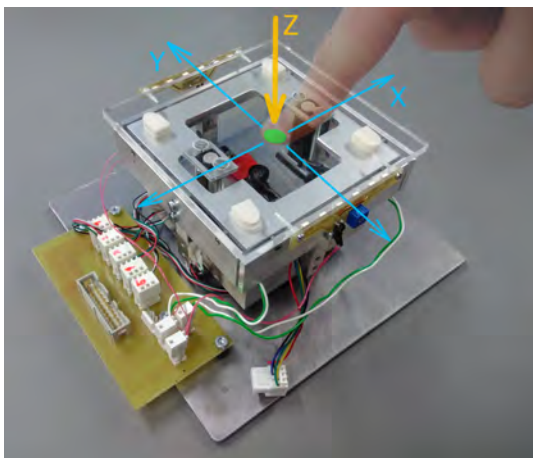


Figure 1: The interface prototype with overlays showing a finger, relative normal and lateral forces, and contact area.

A Micro Load Cell (MLC) sensor CZL635 is used to measure the normal force applied to the top panel up to about 50 N, while four CZL616C MLCs

are used to measure 2D lateral forces up to about 7.65 N along the x and y axes. Sensors data are sampled uniformly at 1176 Hz with 10-bit resolution by means of an Arduino board connected via USB to a host computer.

A micro digital camera placed under the transparent Plexiglas top panel captures images of the contacting fingers (up to 1280×960 pixels and 45 fps), and send them over USB. Visible light is filtered out by putting a cut piece of unexposed developed reversal film (i.e. a black slide) between the lens and the sensor. Two PCB strips with infrared LEDs are attached opposite each other to two sides of the top panel, so that finger-pads touching its surface get illuminated.

Two coil-type vibration actuators Tactile Labs Haptuator mkII are mounted perpendicularly at the lower side of the top panel. Vibratory stimuli are routed as audio signals through a Kemo 031N audio amplifier connected to a digital audio interface at the host computer.

The decoupling of normal and lateral forces represented the main mechanical challenge, however this was an important prerequisite as commercial 3D force sensors with comparable performance usually cost around 700–900 USD, while our low-cost solution uses 5 separate unidirectional MLCs currently priced about 7 USD each. To achieve that, a key step was to rely on precise CNC-milled aluminum components, interconnected by various elements affording controlled deformation of the resulting structure. Since the MLC sensors are made out of single pieces of aluminum with screw holes at both ends, they were used also as building components: The complete structure is resting on the larger MLC measuring normal force, while the four smaller MLCs sensing lateral forces provide support to the sides. Four spring steel wires hold the normal force plate in place. While the wires can withhold vertical forces, they afford horizontal sliding of the force plate due to lateral forces. Attached to each of the four smaller MLCs is a side plate, each using two headless screws that minimize the gap to the force plate while avoiding direct contact with it. In this way, the side MLCs are only engaged when lateral force components are oriented towards them. The Plexiglas top panel is suspended over the force plate by means of rubber-foam spacers fixed with double sided tape, so that vibratory energy is not dissipated through the metal structure.

A software application collects sensor data via the interface's USB connections, analyzes and visualizes them in a graphical interface. The images taken from the camera are processed to compute the position of up to two finger-pads in x-y coordinates relative to the center of the top panel and their contact areas in mm^2 . Tridimensional force data along the x, y and z axes (see Fig. 1) are instead calculated within the application and presented numerically as values in N.

The accuracy of contact area and force measurements were tested and calibrated, while the characterization of the actuators' response is planned and will follow the same procedure used for the previous design (see the appendix of [2]).

The measured quantities are represented graphically as various interactive overlays over a square which symbolizes the top panel of the interface. The computed data are also made available externally by the application for other uses.

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A few examples are currently provided with the interface that generate vibrotactile and auditory feedback controlled by the sensors data, namely: interactive synthesis physics-based models [1] of crushing, scraping and friction, and multiple sine wave oscillators creating beatings. Auditory and vibrotactile stimuli can be set separately, or conversely a same signal can be routed to both the actuators and external audio equipment such as headphones.

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²<http://p3.snf.ch/project-178972>