HaptiTrack: A novel device for the evaluation of tactile sensitivity in active and in passive tasks

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***Abstract*— Several neurological, metabolic and psychological conditions may lead to tactile dysfunctions. Quantitative sensation tests (QST) are currently available for the assessment of tactile sensitivity, including light touch testing, monofilament tests, and vibration-based tests. However, standard QSTs display a high intra- and inter-individual variability. To this end, we developed new interface that generates 2D motion of a contact plate, provides hand and finger tracking, and measures contact force and torque. Due to these multiple features, the device can be a powerful tool for the evaluation of touch in both, active and passive tasks.**

I. INTRODUCTION

The sense of touch allows us to perceive the mechanical properties of the objects through the contact with the skin [1]. Several neurological, metabolic and psychological conditions may lead to tactile dysfunctions, such as paresthesia (abnormal sensation such as tingling or tickling) and hypoesthesia (reduced tactile sensitivity) [2]. Quantitative sensation tests (QST) are currently available for the assessment of tactile dysfunction, including light touch testing, monofilament tests, and vibration-based tests. However, standard QSTs display a high intra- and inter-individual variability. In a preliminary study (currently ongoing) we developed a novel protocol to evaluate tactile sensitivity in type 1 diabetes mellitus by using a custom-made haptic interface delivering passive stimuli, i.e. with the hand stationary. Recent studies highlighted the importance of touch in motor control [3]. Therefore, it may be important to evaluate touch also in active task (e.g., surface exploration and reaching). To this end, we developed new interface that generates 2D motion of a contact plate, provides hand and finger tracking, and measures contact force and torque. Due to these multiple features, the device can be a powerful tool for the evaluation of touch in both, active and passive tasks. The novel haptic interface, the *HaptiTrack* device, will be used for the evaluation of tactile sensitivity diabetes mellitus in future work.

II. MATERIAL AND METHODS

A. Hardware description

The HaptiTrack device is shown in Fig. 1. The device is similar to a pantograph with two orthogonal axes mounted on top of each other for the displacement of the contact surface on a horizontal plane. Each axis consist of a compact single-axis actuator (MISUMI LX3005CP-MX-B1-N-600-FA2), endowed with a precision grade ball screw. The device is endowed with two proximity sensors that switch off the power-supply in case the device position would exceed the allowed range. Each of the two axis is driven by Maxon motor (DCX26L GB KL 24V with planetary gearhead GPX26 C 3.9:1). A control board (SoftHand Board v1.0 by qbrobotics) combined with a 16-bit resolution encoder are used to control the angular position and speed of each motor. Each ball screw is connected to the motor by a rubber-type shaft coupling (Nabeya Bi-tech XGS-25CS-6-6), ensuring high damping capacity. The device is equipped with a sensorized surface with a 3D printed textured plate on top ($100 \times 100 \times 3\ mm$). Four damping components (TAICA Gel Bush A-1) placed between the contact surface and the movable axis reduce high-frequency vibrations generated by the motors. A 6-axis force/torque sensor (ATI Mini45) is placed below the contact plate. Sensing range and resolution are suitable for force/torque measuring within the typical human range [4]. OptiTrack system is used to track the fingertip of the user. Four OptiTrack Flex13 cameras are firmly attached to the metal frame of the device. A rigid body made of a 3D-printed thimble with 4 passive markers ($3\ mm$ of diameter) ensured a reliable tracking.

B. Control algorithm

We tested the capacity of the device to update the position of the plate to follow the finger movement of a participant. A single participant moved her fingertip back and forth on the contact plate (1D motion). The position of the contact surface was updated every 2 ms, according to Eq. 1:

$$\vec{x}_{new} = \vec{x}_{old} + \gamma(\vec{X}_{new} - \vec{X}_{old}) \tag{1}$$

Where $\vec{x}_{new}$ and $\vec{x}_{old}$ are the x and y position of the contact surface in the previous and in the current step, $\vec{X}_{new}$ and $\vec{X}_{old}$ are the current and the previous position of the fingertip measured from the OptiTrack, and γ is the position gain between the user's finger and the contact surface. In different trials, we set the values of gain γ to one of the following values: $\pm 1, \pm 0.8, \pm 0.5, \pm 0.4, 0.0$. At the beginning of each trial, the initial position of the contact

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Fig. 1. The HaptiTrack device. A. The HaptiTrack device fixed inside a safety cage with mounted a OptiTrack Flex13 camera in each corner. B. An exploded view of the HaptiTrack device with the principal mechanical/electronic components. C. An exploded view of the contact surface.

surface was always set to zero. As a contact was detected, $\vec{X}_{new}$ and $\vec{X}_{old}$ were initialized at the current finger position. If the measured force module was $< 0.1\ N$ the contact surface position was not updated.

We used a custom-made software written in C++ and libraries Eigen, Boost, and OptiTrack NatNet to control the apparatus and for the synchronization of the OptiTrack, the ATI Mini45, and the motor encoders.

III. RESULTS

a) vibrations: The vibration along the three axes were recorded with an accelerormenter attached to the contact plate and measured at the two motion speed of 20 and 100 mm/s (Fig. 2A). The peak vibrations along the y axis is likely due to the change in motion direction of the plate at the end of each swept.

b) pursuit gain: Figure 2A illustrates the back-and-forth displacement of the participant's fingertip. The amplitude of movement was larger for positive gains, where the plate was following. Instead, this was restricted to half of the plate's width for $\gamma = -1$.

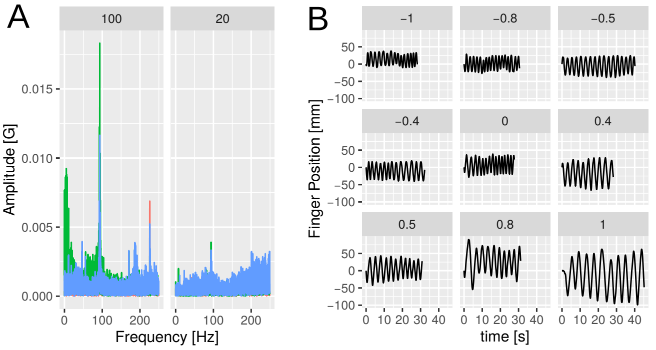

Fig. 2. A) Measured vibration along the three axes (x, y, z) for a synusoid movement along the y axis at two target speed and for the maximum movement width (stroke). B) The back and forth movement of the fingertip (one participant).

By changing the value of γ, it was possible to disentangle tactile and hand motion. If $\gamma = 0$ the contact surface was stationary, if $\gamma = 1$ the contact surface and follow the user's finger on the y-axis (zero tactile motion), and if $\gamma = -1$ the y-axis is in counterphase respect to the user's finger movement direction. We compared the actual and the target position of the plate for differ finger movement and values of gain. As illustrated in Figure 3 the actual position of the plate closely matches the target position (we removed a small offset between the two due to the inertia of the apparatus). The correlation between the target and the actual value of plate position was 0.99 ($p < 0.001$).

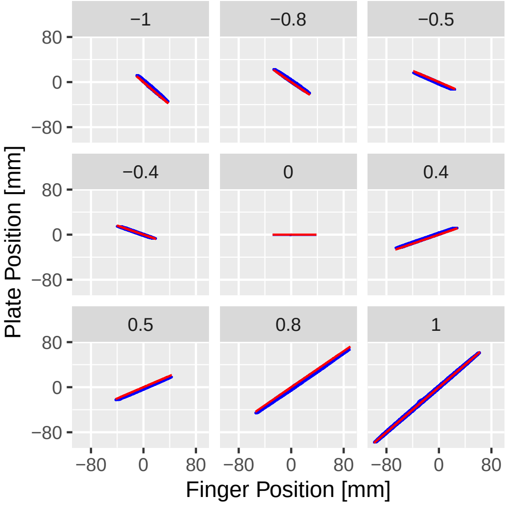

Fig. 3. Finger and Plate position for different values of gain, γ. The label above each panel is the value of gain. Target and actual values are represented in red and blue, respectively

IV. DISCUSSION

Here, we presented a novel haptic device for the study of tactile motion in active and passive tasks. In the preliminary evaluation, the device was able to produce the requested displacement to pursue the finger movement. In future work, this device will be used in behavioral experiment in healthy volunteers and people affected by neurological diseases for the evaluation of tactile sensitivity.

V. REFERENCES

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