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Active calibration of tactile sensors mounted on a robotic hand

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I. INTRODUCTION

Touch is one of the most important human capabilities. If vision can help people to recognize the environment, touch is the fine controller for all motions. Tactile sensors measure information arising from physical contact with the environment and are generally modelled after the biological sense of cutaneous touch, that are crucial for many micro tasks, such as in-hand manipulation.

Here, we focus on the BioTac tactile sensors\textsuperscript{1}, that mimic the human skin, by using a flexible finger-shaped rubber, mounted on a rigid bone-like structure (see Fig. 1). Extensive research has been carried out to calibrate the BioTac sensors, i.e. to derive the relationship between raw values and actual force. For instance, machine learning approaches have been used in [1], [2]. But since these have proved to be time consuming, an alternative, analytic method, has been designed in [3]. Ciobanu et al. [4] established a preprocessing pipeline to overcome the signal’s non-compliances and issues for further processing.

Here, we propose a method to actively calibrate the BioTac sensors embedded on the fingertips of a Shadow Dexterous robotic Hand\textsuperscript{2}. Since this is a common setup in many robotics laboratories, we are confident that the proposed procedure may be of interest to a wide community. The hand fingers sequentially push on a force sensor plate. An automatic procedure converts the static pressure values measured by the BioTac sensor to force values using techniques similar to those in [1]. Finally, the computed force values are compared to those measured on the force plate, and are found to be coherent. Complementary to [3] and [4], in this paper the shadow robotic hand is actively calibrating by moving the tactile sensors. This setup makes the calibration process easy and fast and enable the use BioTacs for force sensing or force regulation if mounted on a hand. The methodology used here is applicable for active calibration of BioTac sensors in a myoelectric/prosthetic hand for precise grasping.

\textsuperscript{1}www.syntouchllc.com
\textsuperscript{2}www.shadowrobot.com
\textsuperscript{3}www.ati-ia.com/
to derive $K$ and $P_0$.

For the force $F$, we simply consider the norm of the three measured components:

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2}. \quad (2)$$

For each BioTac, to reduce the electrode noise perturbation, a *Single Pole Infinite Impulse Response Filter* is applied to the raw static pressure measure. Filtered values $P_i$ at iteration $i$ are expressed in function of the raw measures $\hat{P}_i$ via:

$$P_0 = \hat{P}_0$$
$$P_i = \hat{P}_i + \alpha \cdot P_{i-1} \cdot (1 - \alpha) \quad i > 0, \quad (3)$$

with $\alpha \in [0..1]$ a coefficient that controls the degree by which the weight of a measure decreases based on its age. It is common to set $\alpha = \frac{T_i}{T_s \cdot \tau}$, with $T_i$ the sampling time, and $\tau$ the time constant of the system. Here (as in [4]), we estimate both to be roughly 1 ms, so that $\alpha = 0.5$ provides the best compromise between sensor noise reduction and response reactivity.

Then, $K$ is simply derived by inverting (1):

$$K = P^T \cdot F, \quad (6)$$

with $P^T$ the Moore-Penrose pseudoinverse of $P$.

**IV. RESULTS AND CONCLUSION**

The five sensors parameters are given in Table I. In figure 3, we plot the values of $P - P_0$ and corresponding force measures at the iterations with fore finger in contact with the plate. It can be seen that the points lie on the trend-line of slope $K$. After calibration, we verify the tuned values of $P_0$ and $K$ by running an experiment where the fingers again push the force sensor plate one-by-one, and the values computed with (1) are compared to the force sensor measures. The results are very near (for instance, we obtain a relative error of 5.91% for the fore finger). The same setup is being used to calibrate the electrode array and consequently estimate the force vector and point of force application.

A video of the complete experiment (three movements per finger for calibration, and a fourth for verification) is available at: www.youtube.com/watch?v=k3m6jaVxXBlI

![Image](image1.png)

**TABLE I: Calibrated parameters of the five BioTac sensors.**

<table>
<thead>
<tr>
<th>Finger</th>
<th>thumb</th>
<th>fore</th>
<th>middle</th>
<th>ring</th>
<th>little</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_0$ (Pa)</td>
<td>0.016</td>
<td>0.010</td>
<td>0.013</td>
<td>0.009</td>
<td>0.009</td>
</tr>
<tr>
<td>$K$ (N/Pa)</td>
<td>85</td>
<td>86</td>
<td>106</td>
<td>57</td>
<td>70</td>
</tr>
</tbody>
</table>

![Image](image2.png)

**Fig. 3: Pressure ($P - P_0$) vs Force ($F$) measurements for the fore finger.**

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**REFERENCES**


