Calibration and Test of a Multi-Touch Tactile Object

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***Abstract*— In this work we present different calibration methods for a custom made 36 axis F/T (Force/Torque) sensor used for a multi-touch tactile object. This object will be employed to perform human grasp experiments on contact forces and points. A comparison of the performance of the system in reconstructing contact points locations is reported.**

I. INTRODUCTION

In this work we discuss the calibration procedure of a custom made 36 axis F/T sensor [1] of cubical shape (each face is a 6 axis F/T sensor).

Different patches can be attached on the sensor active faces in order to obtain a multi-shape sensorized object (for example, see fig. 1-a).

To identify the contact point position on a surface patch through the measurements of the corresponding face, we employed the algorithm based on [1] and implemented in the toolbox [2] (which is publicly available).

The multi-shape object will be used for human grasp experiments to simultaneously record contact forces and point locations.

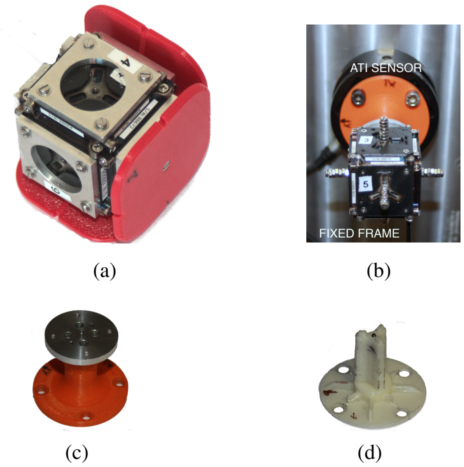

Fig. 1. The senorized object (black and gray cube) with the red patch for a cube shape (a). Calibration setup (b). Flange *Type* 1 (c) and flange *Type* 2 (d).

II. CALIBRATION METHODS

In the calibration procedure here presented we used an ATI Delta force/torque sensor for measuring wrenches applied on the custom sensor and two types of calibration flanges (with known dimension) to fix the device to the ATI sensor (for more detail see also fig. 1-b). Calibration was performed without attaching any surface patch to the active surfaces.

The first flange (see fig. 1-c) is fixed on the 36 axis F/T sensor frame thus, not allowing to measure strain gauge deformations of the corresponding face. The second flange (see fig. 1-d) is fixed on one face of the 36 axis F/T sensor and allows measurement of the strain gauges of all active faces.

The generic active faces deformations are measured by 6 strain gauges.

A. Face to Face Calibration

If the 6 strain gauges of each active face are completely decoupled from those of the others, i.e a wrench applied on a face does not produce any relevant deformation on the strain gauges of the other faces, a face to face calibration procedure can be applied.

This consists of applying a known wrench W_i (in this case measured by ATI Delta force/torque sensor) on a face and correlating it with the strain gauges measurements, as

$$W_i = C_i S_i, \tag{1}$$

where $W_i \in \mathbb{R}^{6\times1}$ is the wrench vector applied on the i-th face, $C_i \in \mathbb{R}^{6\times6}$ is the calibration matrix of the i-th face and $S_i \in \mathbb{R}^{6\times1}$ is the strain gauge measurements of the i-th face.

Now, it is possible to compute the calibration matrix as

$$C_i = W_i S_i^{\dagger} \tag{2}$$

where $S_i^{\dagger}$ is the pseudo-inverse of matrix S_i.

Since the sensor has 6 independent active faces, the calibration method has to be repeated six times (i.e with $i = 1, 2, ..., 6$) and each face will have its calibration matrix.

B. Quasi Total Calibration

In this calibration method we apply a wrench on each face at a time in sequence, starting from active face 1 to active face 5.

For this calibration method flange 1 (see fig. 1-c) is used. This flange does not allow to apply a wrench on the active face where the flange is fixed. Supposing to fix the flange on face 6 and considering to collect load wrenches ($W_i \in \mathbb{R}^{6\times1}$ with $i = 1, ..., 5$) applied on each face, a matrix

$$\bar{W} = \left[\begin{array}{c|c|c|c|c} W_1 & 0 & 0 & 0 & 0 \\ 0 & W_2 & 0 & 0 & 0 \\ 0 & 0 & W_3 & 0 & 0 \\ 0 & 0 & 0 & W_4 & 0 \\ 0 & 0 & 0 & 0 & W_5 \end{array}\right], \tag{3}$$

where $0 \in \mathbb{R}^{6\times1}$ is a vector of zero elements, is obtained.

Consequently, we collect the strain gauge measurements in a matrix

$$\bar{S} = [\; S_1 \quad S_2 \quad S_3 \quad S_4 \quad S_5 \;], \tag{4}$$

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[1]the device was designed and built by IIT, Italian Institute of Tecnology

where $S_i \in \mathbb{R}^{36\times 1}$, with $i = 1, \dots, 5$, is the measurement of all strain gauges when wrench is applied on i-th face. Now it is possible to compute the calibration matrix $\bar{C} \in \mathbb{R}^{30\times 36}$ as

$$\bar{C} = \bar{W}\bar{S}^{\dagger}. \quad (5)$$

C. Total Calibration

In this calibration method we apply a wrench on each face at a time in sequence, starting from active face 1 to active face 6.

For this calibration method flange 2 (see fig. 1-d) is used. This flange allows to apply a wrench also on its active face. Supposing to fix the flange on face 6 and considering to collect load wrenches ($W_i \in \mathbb{R}^{6\times 1}$ with $i = 1, \dots, 6$) applied on each face, a matrix

$$\hat{W} = \left[\begin{array}{c|c|c|c|c|c} W_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & W_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & W_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & W_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & W_5 & 0 \\ W_1^6 & W_2^6 & W_3^6 & W_4^6 & W_5^6 & W_6 \end{array}\right], \quad (6)$$

where $0 \in \mathbb{R}^{6\times 1}$ is a vector of zero elements, is obtained.

Consequently, we collect the strain gauge measurements in a matrix

$$\hat{S} = [\ S_1 \quad S_2 \quad S_3 \quad S_4 \quad S_5 \quad S_6\ ] \quad (7)$$

where $S_i \in \mathbb{R}^{36\times 1}$, with $i = 1, \dots, 6$, is the measurement of all strain gauges when wrench is applied on i-th face. Now it is possible to compute the calibration matrix $\hat{C} \in \mathbb{R}^{36\times 36}$ as

$$\hat{C} = \hat{W}\hat{S}^{\dagger} \quad (8)$$

D. Calibration Result

For the custom made 36 F/T sensor considered in this paper, after a certain wrench intensity threshold, some face coupling phenomena occurs. Thus the best calibration procedure is the *Total Calibration*. Indeed, with this calibration method we take into account the total deformation of entire sensor allowing, in this case, a better computation of the wrenches applied.

III. CONTACT POINT COMPARISON

To assess the accuracy of the contact point reconstructions, a comparison between the algorithm presented in [1] and implemented in [2] applied on the custom made sensor and a commercial one was performed.

The algorithm was employed with a surface patch for the cubical shape (i.e we use one face of the 36 axis F/T sensor). Then the same surface patch was fixed on the ATI Nano 17 commercial F/T sensor.The contact surface was a square of 46×46 mm with 8 points. These points lie on the edges of a 26×26 mm square.

The experimental task was performed touching the points (one at a time) with fingertip and then touching the center of the surface patch.

The accuracy of our sensor after the calibration was in the order of 3 mm, which is enough for our purposes. In fig. 2 - 3 we report the results.

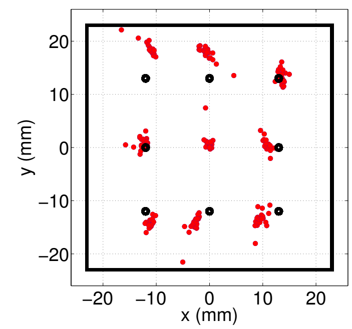

Fig. 2. Contact points algorithm tested with face 5 of the sensorized object. Reference points (black) were touched with fingertip (one at a time). Red points are the algorithm results.

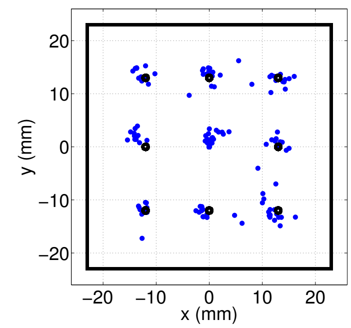

Fig. 3. Contact points algorithm tested with ATI Nano 17. Reference points (black) were touched with fingertip (one at a time). Blue points are the algorithm results.

IV. CONCLUSIONS

In this work we present three different calibration methods for a 36 axis F/T sensor. This sensor is the core of a sensorized object used for contact point computations in human grasping tasks.

The object can assume different shape by simply changing the patches attached on the sensor.

Moreover, we report a comparison between contact point detection applied on a commercial F/T sensor and on sensorized object.

In the contact point detection we achieve an accuracy in the order of 3 mm, which is suitable for our purposes.

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