Robotized measurements : autonomous geometric and vibro-acoustic characterization of structures

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Introduction

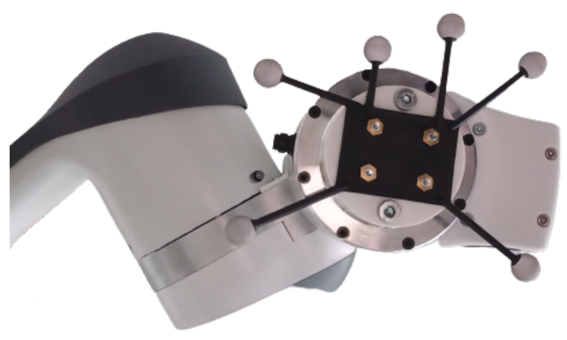
In the near future, robotics are to become an essential asset in the development of an ageing industry, by offering autonomous and reproducible means of manufacturing and production control. In particular, metrology operations, aiming to ensure the mechanical compliance and manufacturing quality of produced parts, are perfect candidates for automation. We propose an original and versatile robotic setup, able to perform both geometric and acoustic characterizations of unknown structures. This solution essentially relies on the use of a robotic arm, fitted with appropriate sensors, such as a depth camera, or an acoustic intensity probe.

Robotic arm absolute positioning precision

Absolute positioning precision assessment

In order to assess the absolute positioning precision of the robotic arm to be used, we opted for a multiple infrared cameras tracking tool - the *OptiTrack* - which provides the ability to measure the absolute position of spheric markers with a sub-millimetric accurcy.

As such an installation does not yield any information about the markers orientations, we conceived a rigid structure holding 7 markers, in a three dimensional and asymmetrical layout, in order to make up for this lack.



Using this so-called rigid body fixed on an Panda robotic arm, two rounds of measurements were carried out using 300 evenly sampled learning configurations and 10 randomly picked testing configurations.

	Average absolute positioning error	
	Learning error	*Testing error*
Without calibration	4,85 m	0,91 m
With calibration	0,0066 m	1,06 m

Absolute positioning precision improvement

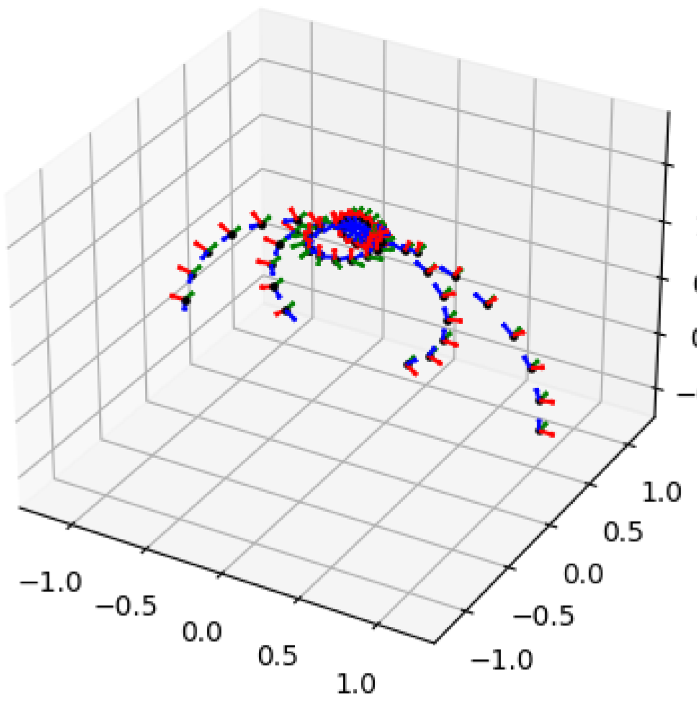
Given the poor absolute positioning precision of the robotic arm, and the significance of this aspect in order to obtain relevant metrology results, we designed the following hybrided calibration procedure :

1. **Geometric model definition** According to [1], build an *irreductible* and *complete* geometric model of the manipulator, which links the robotic arm configuration to its end-effector position, and highlights the seeked geometric parameters vector :
$$\pi = (\pi_{Base}, \pi_{Robot}, \pi_{Tool})$$
2. **Measurements design and implementation** Perform a sufficiently high number of position measurements, according to a predefined learning set of configurations [2];
3. **Geometric parameters optimization** Following the Gauss-Newton method depicted in [3], compute an estimation of π minimizing the euclidian distance between the computed and measured absolute positions.

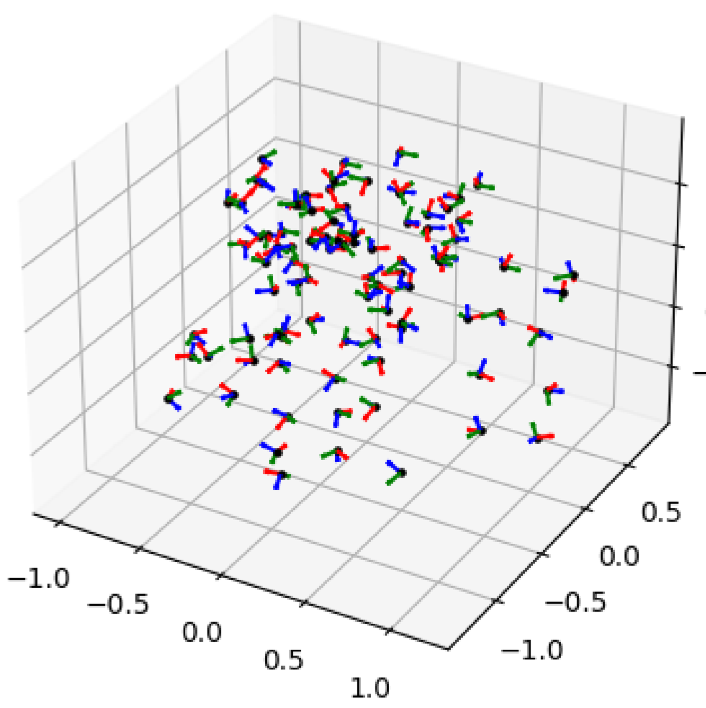
Implementing this procedure on the learning set, significant improvements were observed, whereas the testing set revealed flaws in the measurements design and parameters optimization steps.

Measurements design optimization

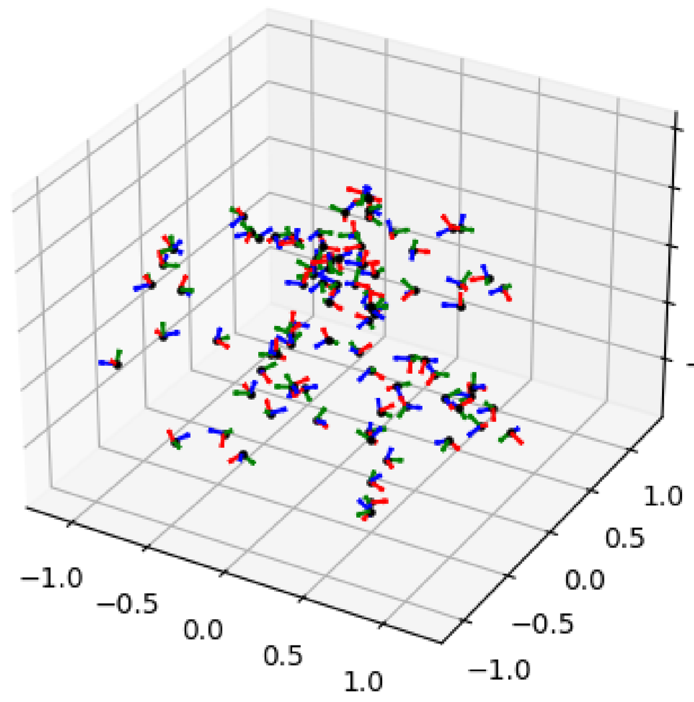
In order to reduce the average error obtained on the testing set, we tried to narrow the learning set to the configurations maximizing the parameters *identifiability*.



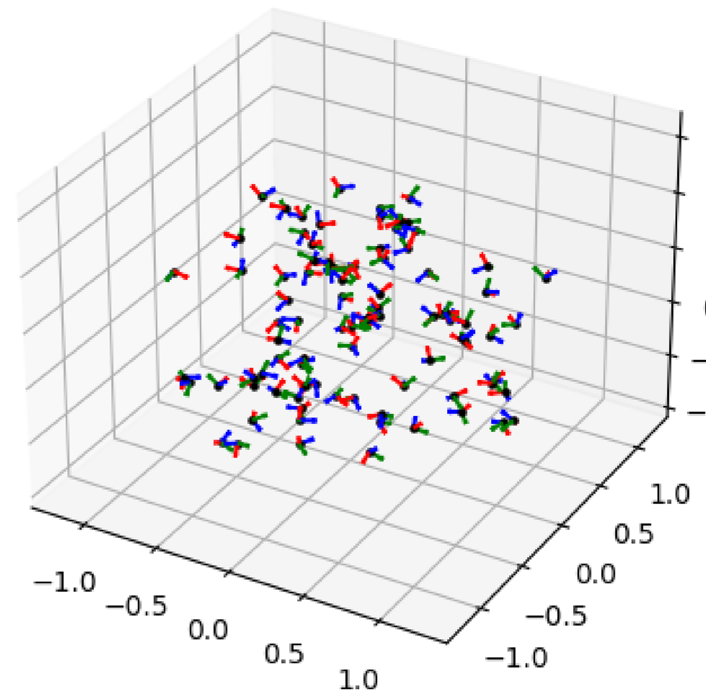
Even samples (lowest identifiability)



Random

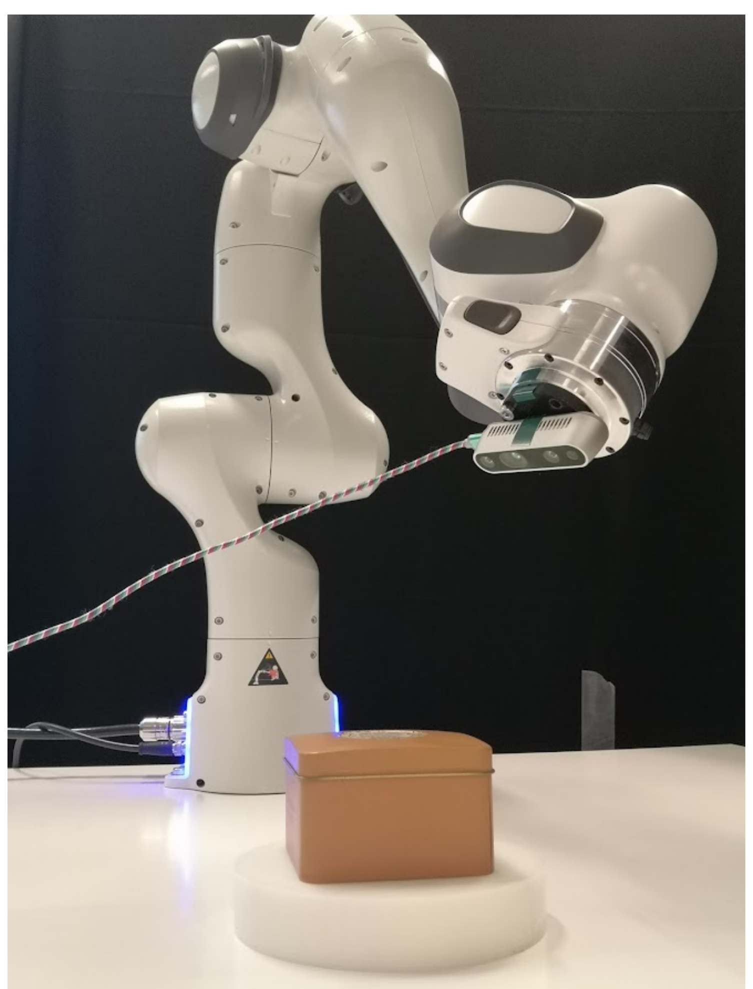


Genetic algorithm



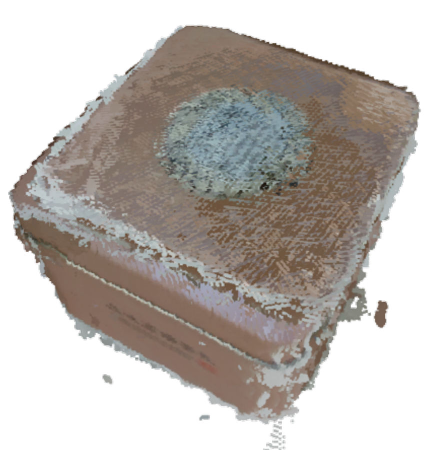
Greedy algorithm (highest identifiability)

Geometric characterization



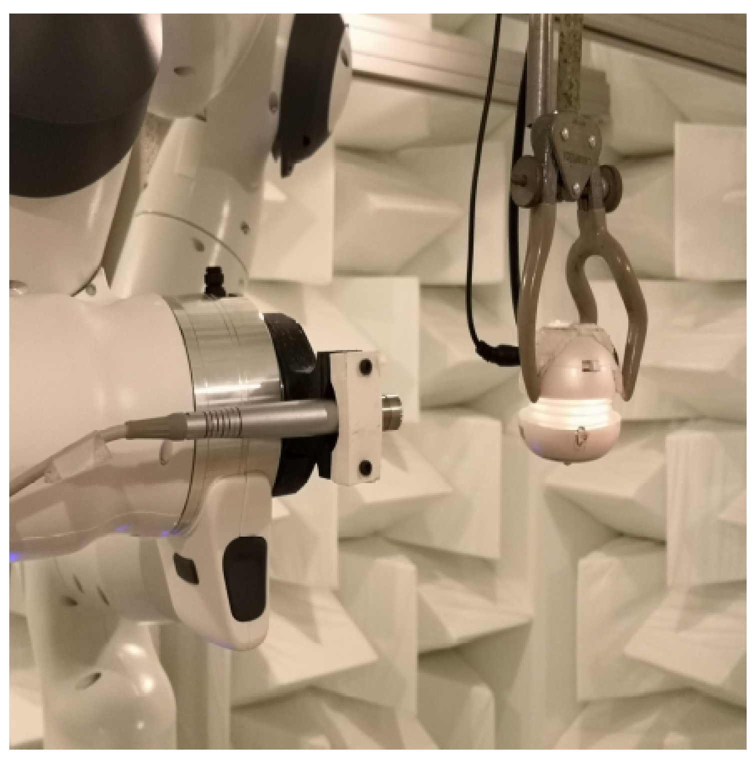
Depth camera setup

ICP matching

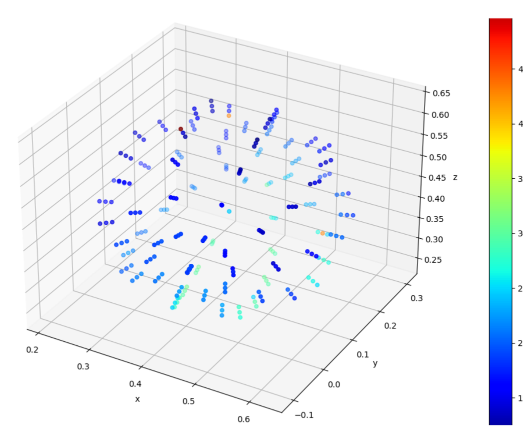


RTABMAP matching [5]

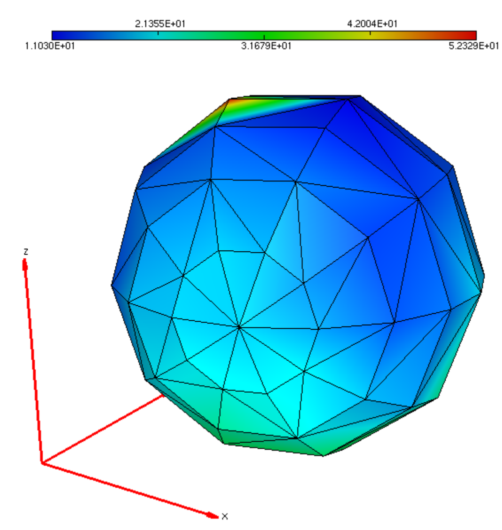
Acoustic characterization



Microphone setup



Raw pressure measurements



FreeFEM integration [4]

References

[1] A. Pashkevich, "Computer-aided generation of complete irreductible models for robotic manipulators", *3rd International Conference of Modeling and Simulation*, 2001.

[2] A. Klimchik et al., "Advanced robot calibration using partial pose measurements", *18th International Conference on Methods and Models in Automation and Robotics*, 2013.

[3] J. Alexandre dit Sandretto, "Certified calibration of parallel cable-driven robots", University of Nice Sophia Antipolis, France, 2013.

[4] Z.-W. Luo et al., "Near-field acoustic holography with three-dimensional scanning measurements", *Journal of Sound and Vibration*, 2019.

[5] M. Labbé et al., "RTAB-Map as an open-source lidar and visual simultaneouslocalization and mapping library for large-scale and long-term online operation", *Journal of Field Robotics*, 2019.

Perspectives

→ **Implement and evaluate new measurements design and parameters optimization methods** within the robotic arm calibration process;

→ **Improve and further automate both characterization processes** : calibration integration, post-processing, autonomous measurements definition and refinement, continuity between processes, etc.