

# Grasp Quality Evaluation in Underactuated Robotic Hands

Maria Pozzi<sup>1</sup>, Ashok M. Sundaram<sup>2,3</sup>, Monica Malvezzi<sup>1</sup>, Domenico Prattichizzo and Máximo A. Roa<sup>2</sup>

<sup>1</sup>Università degli Studi di Siena, Siena, Italy and Istituto Italiano di Tecnologia (IIT), Genoa, Italy.

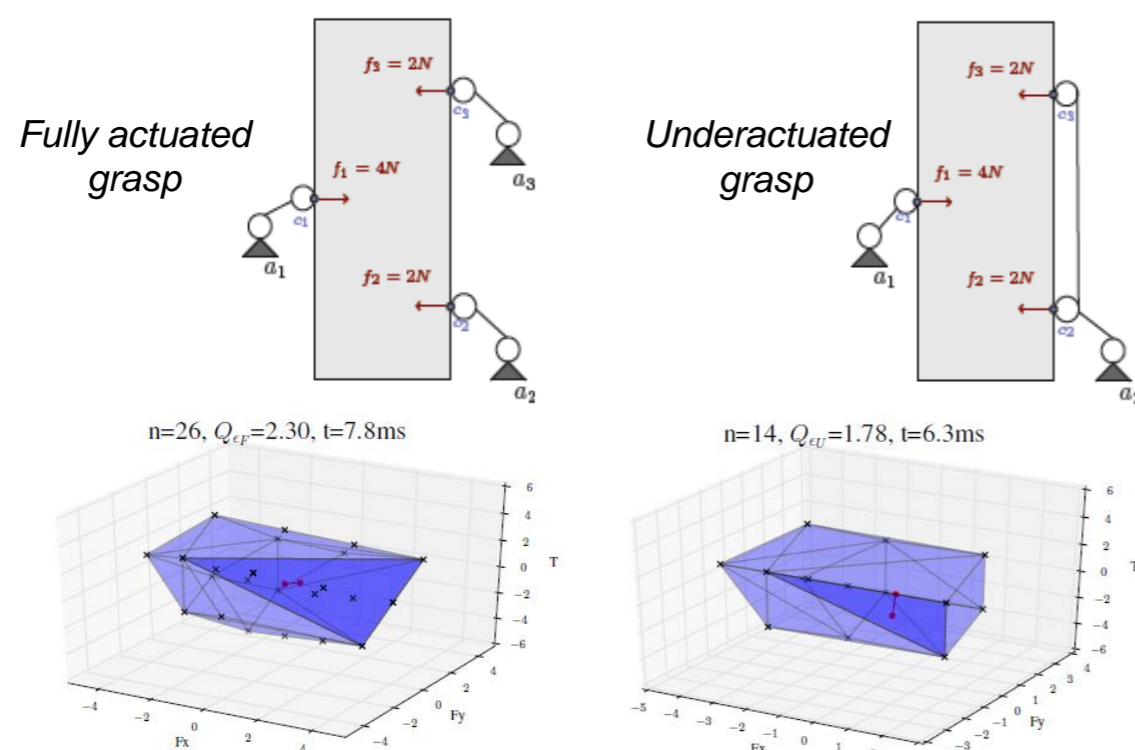
<sup>2</sup>German Aerospace Center (DLR), Germany. <sup>3</sup>Bonn-Rhein-Sieg University of Applied Sciences, Germany

## Abstract

Underactuated and soft hands are gaining attention in the grasping community mainly due to their simple kinematics, intrinsic compliance and versatility for grasping objects even in non structured scenarios. The evaluation of the grasping capabilities of such hands is a challenging task. This work revisits some traditional quality measures developed for multi-fingered, fully actuated hands, and applies them to the case of underactuated hands.

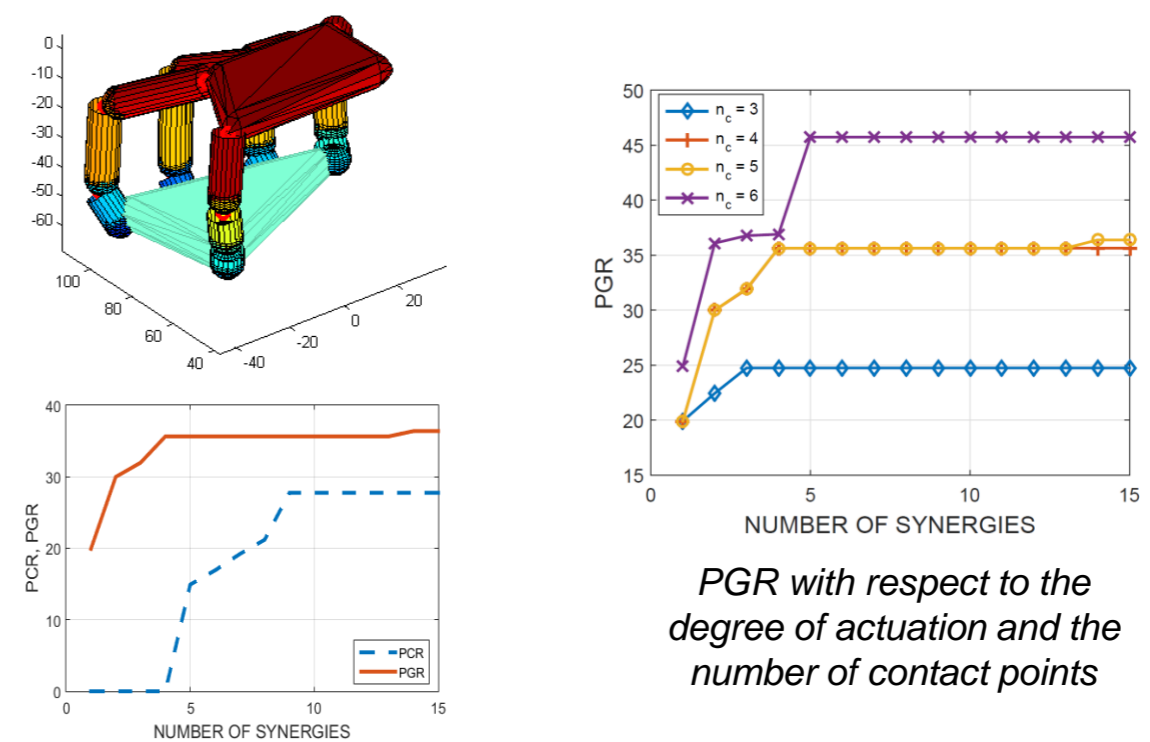
## Measures Based on Wrench Space

A widely used criterion for evaluating the force closure of a grasp is the computation of the largest minimum resisted wrench ( $Q_{\epsilon}$ ) [1], that represents the maximum perturbation wrench that a grasp can resist in any direction. In this work, we reconsider the quality measures based on wrench space analysis and revise their assumptions in order to apply them to the case of underactuated hands.



## Contact and Grasp Robustness

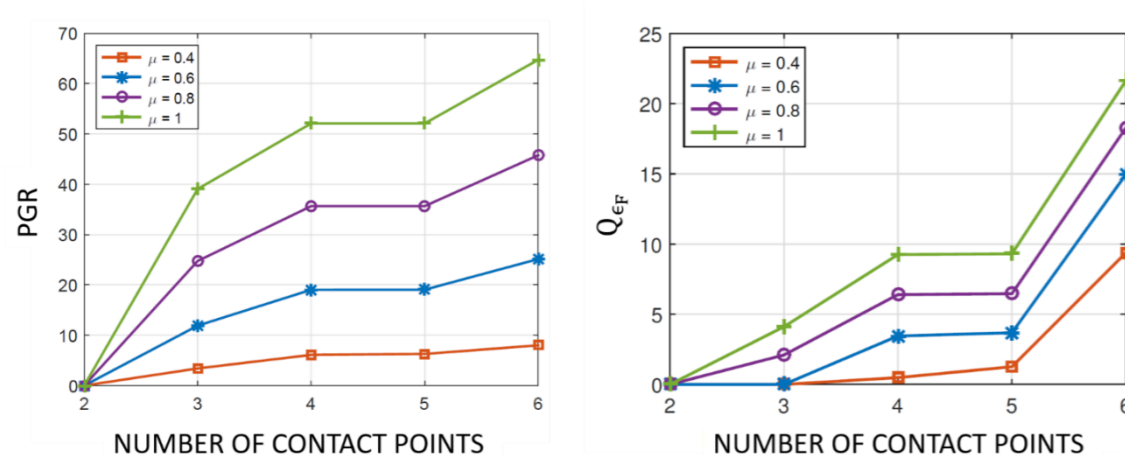
The Potential Contact and Grasp Robustness (PCR, PGR) are grasp quality indexes that consider the main grasp properties, i.e. position of the contact points, friction coefficient, maximum and minimum applicable forces, but also the structure, the actuation system, and the controllable forces of the robotic hand [2].



PCR and PGR for a grasp with five contact points

## Results of the Simulations for an Anthropomorphic Hand with 20 DoFs

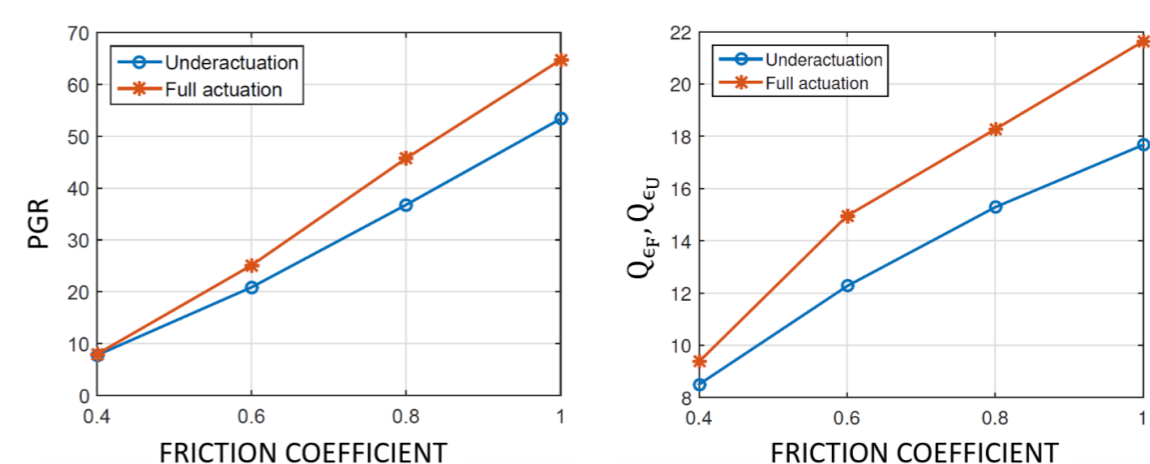
### Fully actuated grasps



In both cases the grasp quality:

- is non-decreasing when the number of contact points increases;
- does not increase substantially between the grasps with 4 and 5 contacts;
- improves considerably for the power grasp with 6 contacts;
- increases when the friction coefficient increases.

### Underactuated grasp with 6 contacts



Even considering an underactuated grasp, PGR and  $Q_{\epsilon F}$  and  $Q_{\epsilon U}$  have similar trends:

- the quality is higher for the fully actuated case;
- the quality increases when the friction coefficient increases.

## References

[1] C. Ferrari and J. Canny, "Planning optimal grasps," in Proc. IEEE Int. Conf. Robotics and Automation - ICRA, 1992, pp. 2290–2295.

[2] M. Pozzi; M. Malvezzi; D. Prattichizzo, "On Grasp Quality Measures: Grasp Robustness and Contact Force Distribution in Underactuated and Compliant Robotic Hands," in IEEE Robotics and Automation Letters, vol. PP, no. 99, pp. 1-1