Computation of Realistic Contact Forces in Grasping

Katharina Hertkorn, Maximo A. Roa, Thomas Wimböck, and Christoph Borst

Introduction

Traditional approaches:

- contact points are planned before calculating the contact forces
- grasp is ranked according to some grasp quality
- Assumption: maximum contact force is smaller or equal to one
- But: maximum force that a robotic finger can apply in a certain direction
  - changes drastically within its workspace
  - depends on the torque limits of the actuators

This work presents:

- a computation of physically achievable contact forces for fingertip grasps
- a modified ray-shooting algorithm to compute the maximal magnitude of an external wrench that the grasp can resist

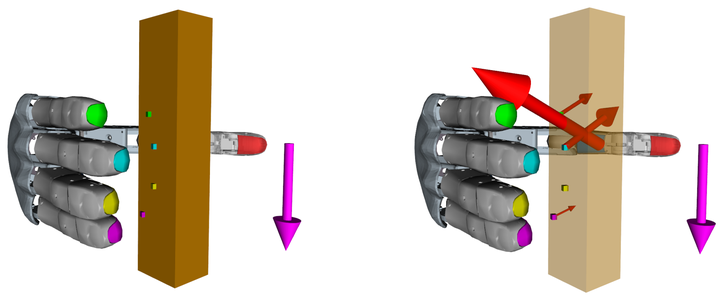


Fig. 1. Pink: direction of gravity
Maximum force of the object using a traditional approach: 0.99N; using physically achievable forces: 10.93N.

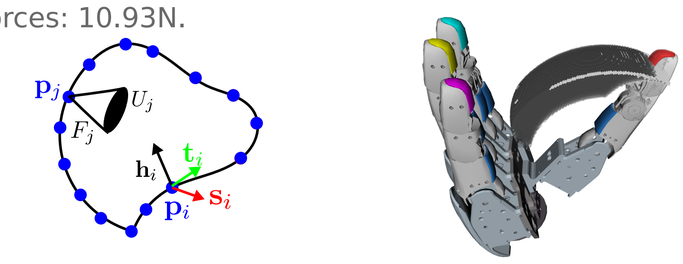
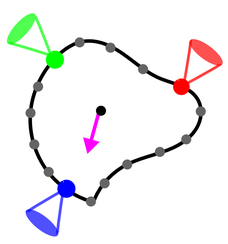


Fig. 2. The object is represented as a pointcloud. Intersecting the workspace of the robotic hand with the object leads to reachable points and corresponding joint configurations

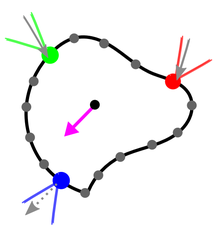
Method

To overcome the limitation of normalized fingertip forces, a generalization of a ray-shooting algorithm [1] is used to calculate the contact forces and the maximal magnitude of the external wrench taking the achievable forces into account.



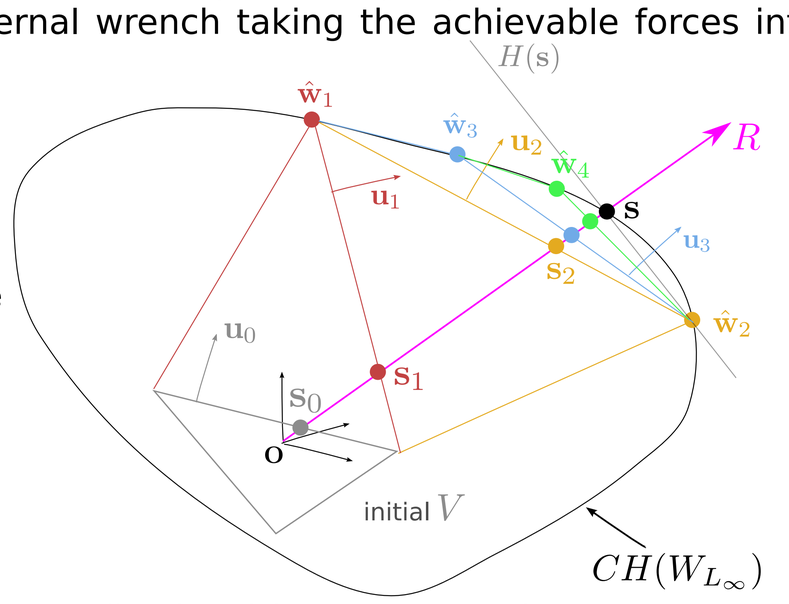
Compute reachable contact points [2]

Initialize the ray-shooting algorithm in wrench space

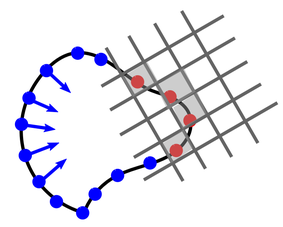


Find the projection of $\mathbf{u}_i$ in the friction cones

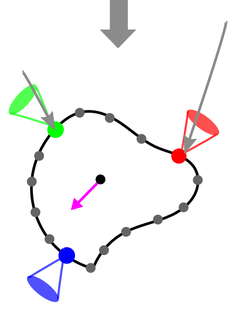
Iterative search for the intersection point $\mathbf{s}$



R: direction of the external wrench
$\mathbf{s}$: intersection between convex hull and R, maximal magnitude of the external wrench
$\mathbf{u}_i$: search direction in wrench space
$\hat{\mathbf{w}}_i$: maximal direction in search direction



Use a modified version of the Voxmap-Pointshell Algorithm to compute the reachable points and the joint configuration of the robotic hand

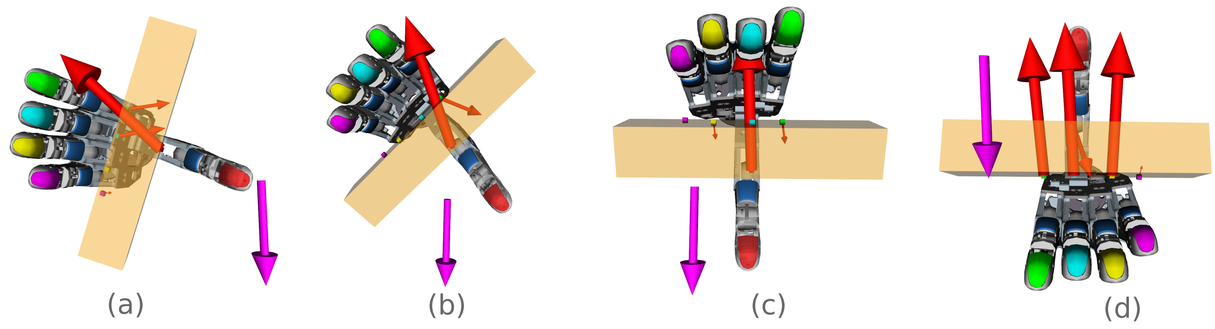


Find the maximal achievable contact forces in the projected direction

Calculate the maximal wrench $\hat{\mathbf{w}}_i$ taking into account the Minkowski sum of the achievable contact wrenches

Evaluation and Discussion

The DLR-HIT Hand II has five modular fingers. Its joint limits are $\tau_{\min} = -1\mathrm{Nm}$ and $\tau_{\max} = 1\mathrm{Nm}$. The workspace of each finger is voxelized with 0.001m and the external wrench represents the gravity force on the object. The object has a mass of 0.5kg and weighs $\|\mathbf{w}_{\mathrm{ext}}\| = 4.91\mathrm{N}$.



	(a)	(b)	(c)	(d)
Rotation angle	20°	45°	90°	-90°
Max. external force	9.86N	10.09N	8.11N	30.95N

Average calculation time of [1]: 5.9ms (min 2.9ms, max 12.0ms)
Average calculation time of this algorithm: 7.8ms (min 3.1ms, max 13.8ms)

The algorithm presented can be used to adapt the contact forces to changes in the external wrench and to monitor the maximum external wrench that can be counteracted by the robotic hand. This allows the robot to predict grasp failures due to movements of the grasped object, or to define online the limitations of manipulation actions on the grasped object.

[1] Y. Zheng, M. Lin, and D. Manocha, “A fast n-dimensional ray-shooting algorithm for grasping force optimization,” in Proc. IEEE Int. Conf. on Robotics and Automation, 2010, pp. 1300–1305.
[2] M. A. Roa, K. Hertkorn, C. Borst, and G. Hirzinger, “Reachable independent contact regions for precision grasps,” in Proc. IEEE Int. Conf. on Robotics and Automation, 2011, pp. 5337–5343.

katharina.hertkorn@dlr.de

DLR Deutsches Zentrum für Luft- und Raumfahrt