

# Physics Guided Grasp Pose Synthesis

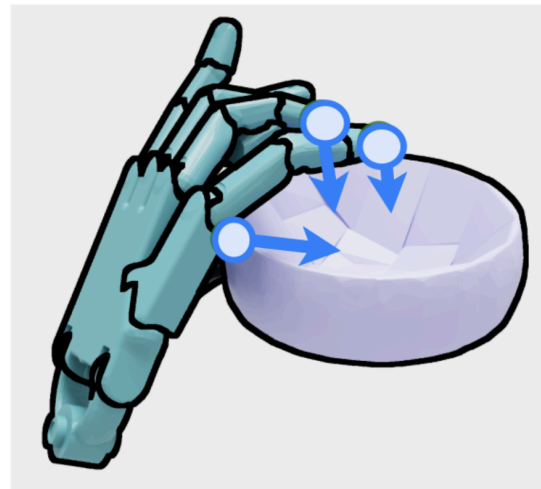
Contact:	Markus Hennig <markus.hennig@uni-paderborn.de>, Pia Bideau <pia.bideau@inria.fr>
Scope:	Project thesis / Master's thesis by arrangement
Start:	From mid October or by arrangement

## Motivation

Object grasping with robotic grippers is a challenging problem due to the large variation in gripper designs and the fact that a single object can often be grasped in multiple ways depending on the intended task. This makes it important to develop algorithms capable of synthesizing diverse grasp poses for a given object.

Existing approaches to grasp synthesis typically rely on either sampling-based algorithms [1,2,3] or simplified force-closure analysis [4,5], each with distinct trade-offs. While sampling-based approaches offer fast inference, they often generate limited grasp diversity due to biases in the training data and objective functions; in contrast, optimization-based methods provide greater physical accuracy but are computationally expensive at inference time.

Achieving both high *computational efficiency* and high *grasp diversity* remains a challenge [6].



Source: GraspQP, CoRL 2025

## Task Description

The goal of this thesis is to develop a novel approach for learning based grasp synthesis, that is fast at inference and captures the fundamental criteria of real world physics:

- **Force closure:** whether the set of contacts can generate forces and torques in all required directions to resist arbitrary disturbances and ensure grasp stability.
- **Penetration constraints:** whether the grasp is physically feasible, meaning that contact is maintained while avoiding interpenetration between the hand, object, and surrounding environment.

We will develop novel loss functions, that are reflecting those physical properties such that during training the goal is not only to reconstruct grasps present in training datasets, further more this allows to guarantee physical plausibility. As a result, grasps not present in the training data but physically feasible can also achieve low loss values, increasing grasp diversity and improving generalization beyond the observed dataset.

The approach will be evaluated in Simulation, most preferably in IsaacSim:

- Grasp quality in simulation. Grasp quality is captured by evaluation measures such as penetration, success, contact, diversity, speed and compared with current state of the art approaches.
- Adaptation to unseen object categories and object poses.
- Validity for different robotic grippers (e.g. two point gripper, dextrous grippers).

## Requirements

- High motivation to solve robotic challenges and to work in an international team.
- Exceptionally high level of personal commitment and a self-driven working style.
- Strong proficiency in Python programming and version control using GitHub for reproducible software development. Familiarity with C++ is considered an advantage. Experience with robotics software frameworks such as ROS, Isaac Sim, and PyBullet is a plus.
- Basic understanding of robotic manipulation, including grasp stability, contact dynamics, and kinematic and joint-space control is a plus.

## References

- [1] A. Miller and P. Allen. Graspit! a versatile simulator for robotic grasping. *Robotics Automation Magazine, IEEE*, 11(4):110 – 122, 2004. doi:[10.1109/MRA.2004.1371616](https://doi.org/10.1109/MRA.2004.1371616).
- [2] J. Huh, B. Lee, and D. D. Lee. Constrained sampling-based planning for grasping and manipulation. *ICRA 2018*. doi:[10.1109/ICRA.2018.8461265](https://doi.org/10.1109/ICRA.2018.8461265).
- [3] A. Mousavian, C. Eppner and D. Fox. 6-dof graspnet: Variational grasp generation for object manipulation. *CVPR 2019*.
- [4] M. Liu, Z. Pan, K. Xu, and D. Manocha. New formulation of mixed-integer conic programming for globally optimal grasp planning. *IEEE Robotics and Automation Letters*, 5(3):4663–4670, 2020.
- [5] L. Han, J. Trinkle, and Z. Li. Grasp analysis as linear matrix inequality problems. *IEEE Transactions on Robotics and Automation*, 16(6):663–674, 2000. doi:[10.1109/70.897778](https://doi.org/10.1109/70.897778).
- [6] R. Zurbrügg, A. Cramariuc and Hutter, M. (2025). GraspQP: Differentiable Optimization of Force Closure for Diverse and Robust Dexterous Grasping. *CoRL 2025*.