Context & Problem Formulation

Autonomous commissioning (order picking) has become a topic of great interest in logistics. In this context, we developed the APPLE (Autonomous Picking & Palletizing) research platform shown in Fig. 1. It is capable of autonomously picking unstructured goods from a storage location, subsequent placement on a standard EUR pallet and transport of the filled pallet to a target location.

Regarding grasp motion generation and execution, often sense-plan-act architectures based on pre-computed grasps and sampling-based path planners are employed. Planning motions in this fashion is time-consuming, often results in unnatural motions and it is not easily possible to incorporate state constraints or react to unforeseen disturbances. Also, sampling-based planners are ill-suited to incorporate contact events which are an inherent feature of any grasping/manipulation task.

Redundant Grasp Formulation

Instead of fully constraining pre-grasp wrist poses, we suggest a redundant formulation in form of grasp envelope constraints as shown in Fig. 2. For the given application, we exploit the low pre-grasp pose sensitivity of the employed grasping device. The gripper is under-actuated and offers additional manipulation capabilities by conveyor belts on the inside of its fingers. These are used to ‘pull’ the target object into a firm envelope grasp.

Stack of Tasks for Grasp Motion Generation

We cast our grasp envelopes in the Stack of Tasks (SoT) framework and formulate a Hierarchical Quadratic Programming (HQP) problem whose solution yields locally optimal joint velocities at each time-step (see Fig. 3). The local nature of the approach requires to segment the motion into phases: grasp approach, object retrieval, object place, gripper extract.

The approach generates reactive motions on-the-fly and is able to exploit the redundancy obtained by our grasp formulation. Collision avoidance is incorporated by formulating appropriate constraints to the underlying optimization problem for simplified geometries (spheres, capsules, planes). It is straightforward to incorporate additional desiderata such as, e. g., desired gripper orientations during object transit.

For future work, we plan to exploit another benefit of online control-based motion generation: the ability to take sensory feedback into account. The utilized SoT framework allows to specify desired task dynamics and it should be straightforward to modulate these with feedback from, e. g., wrist force sensors to adjust grasp motions on-the-fly.