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Knowledge Representations for Planning Manipulation Tasks

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Abstract

A complex manipulation task for a robot has to be planned on different levels of abstraction before it can be executed on a real system. At a high-level of abstraction, a task planner generates a sequence of subtasks from a given abstract command, its pre- and postconditions and a current world model. To restrict the already huge search space of the task planner, aspects like geometric information are not contained in the world model at this level. The task planner then assigns the subtasks to planners on a lower level of abstraction like path planners or grasp planners. These planners rely on geometric information to compute their solutions. However, without considering geometric information the task planner cannot determine good parameters for these low-level planners. Therefore, the derived plans may not be valid for a given situation and may require backtracking.

Knowledge representations can bridge the gap between these planning levels and thereby enable scene reasoning. The kinematic capabilities of a robot are one aspect the task planner has to be aware of. Therefore this book introduces a novel general representation of the kinematic capabilities of a robot arm. The *versatile workspace* is defined to describe in which orientations the end effector attached to a robot arm can reach a position. The *capability map* is a calculable representation of the versatile workspace that allows to determine how well regions of the workspace are reachable. It accurately represents the versatile workspace of arbitrary arm kinematics and enables autonomous task-specific reasoning. Furthermore, its visualization scheme is intuitively comprehensible for the human.

The versatile applicability of the capability map is shown by examples from several distinct application domains. The workspace of several robot arms is visualized and analyzed. It is shown how the capability map can be used to compare the abilities of different robot arms. In human-robot interaction, the capability map is used to objectively evaluate a bi-manual interface for tele-operation. The results can also supplement the design process for humanoid robot design. In low-level geometric planning, the capability map is used to reduce the search space and to parameterize path planners and grasp planners. Thus, in a manipulation task for a humanoid robot more human-like motion is planned while simultaneously the computation time is reduced. In high-level task reasoning, the capability map is used to evaluate how well a robot is suited for a task. In an example a humanoid robot has to perform a task involving 3D trajectories. Regions are extracted from the capability map that permit the task execution and the suitability of the robot is inferred.

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