A geometrical approach to planning manipulation tasks in robotics.

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Abstract

We propose a geometrical approach to planning manipulation tasks where the manipulation problem appears as a strongly constrained case of the coordinated motion problem of several bodies [1] [2] [3]. (To the best of our knowledge, this problem has been first addressed in [1]). The environment contains *obstacles* (fixed bodies), *objects* (movable bodies that do not have their own capacity of motion) and a *robot* (moving bodies that can displace the objects). We consider the space CS of all configurations of objects and robot. The free configuration space FS is the subspace of CS where bodies do not overlap.

We call PLACEMENT the subspace of FS containing all valid placements for all objects, i.e. placements that verify some given geometric relations between the objects and the environment. A *transit path* is a path in PLACEMENT where the configuration parameters of all the objects remain constant along the path (the robot moves alone).

An object can be *grasped* by the robot if the respective positions of the object and of the robot verify some given geometric relations. GRASP is the subspace of FS where an object is grasped and all the other objects are placed. A *transfer path* is a path in GRASP such that the geometrical relation between the positions of an object and the robot is fixed and all the other objects are placed and fixed.

A *manipulation problem* can be then defined as follows : an initial configuration *i* and a final (completely or incompletely specified) configuration *f* being given, do there exist a configuration *j* verifying *f* and a connected sequence of transit and transfer paths between *i* and *j* ? (This is the decision problem). If the answer is yes, give such *j* and sequence. In this case, we said that *i* and *j* are *m-connected*, and we call the sequence a *m-path*.

We show that the decision problem is polynomial for a given environment and that the complete problem is decidable. The proof has two parts. First, a reduction property shows that two configurations of a same connected component of GRASP∩PLACEMENT are m-connected.

Secondly, we build a cell decomposition of GRASP∩PLACEMENT using a cylindrical algebraic decomposition of CS; beside the "natural" adjacency, we introduce the adjacency by transit and transfer paths. For a given environment, the resulting graph can be build in polynomial time. Finally, we show that any manipulation problem can be transformed in polynomial time into a path finding problem in this graph.

For the complete problem, we prove that we can find a m-path in finite time, but its length depends not only on the number of obstacles and objects, but also on the geometry of the environment.

[1] Wilfong **Motion planning in the presence of movable obstacles.** *ACM Symp. on Computational Geometry, 1988.*

[2] Laumond, Alami **A geometrical approach to planning manipulation tasks (1) : the case of a circular robot amidst polygonal obstacles and a movable circular object.** *Technical Report LAAS/CNRS 88314, 1988.*

[3] Alami, Siméon, Laumond **A geometrical approach to planning manipulation tasks (3) : the cas of discrete placements and grasps.** *Technical Report LAAS/CNRS 89045, 1989.*