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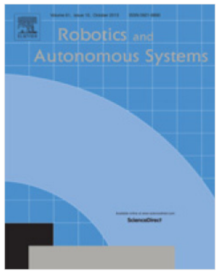

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Partial Convex Hull Algorithms for Efficient Grasp Quality Evaluation

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Abstract

We present two algorithms to efficiently determine the value of two grasp quality metrics formerly proposed in literature. The first one is heavily used in practice but has some drawbacks, e.g., it is not scale invariant and it does not focus on the disturbance forces that will occur in practice when the robot grasps an object. The second one overcomes these limitations, but is rarely used because it is computationally too demanding. The two algorithms we propose are based on the common intuition that both metrics can be efficiently computed through a modified version of the QuickHull algorithm that is commonly used to compute convex hulls. In both cases it is possible to establish when enough information has been generated to determine the desired value, and then stop the construction of a suitably defined convex hull. Extensive numerical evaluations demonstrate that our algorithms provide substantial computational gains when compared with the state of the art. The speedup provides an immediate benefit to planners using grasp quality metrics to guide the search through the space of possible grasps.

Keywords: Grasp quality metrics; grasp planning; computational geometry.

1. Introduction

The ability to restrain an object with a multifingered robotic hand is a critical component in numerous robotics and automation processes [1–4]. When a geometrical model of the object is available, a grasp planning algorithm can be used to determine suitable contact points and forces. In general, for a given object and robotic hand there exist multiple configurations that can achieve a successful grasp, and therefore a quality metric is often used to select which one should be used, or to inform the search through the space of possible grasps. Algorithms capable of efficiently evaluating the quality of a candidate grasp are therefore essential to accelerate the planning process. The grasp metrics we consider in this paper evaluate the ability to resist an external disturbance to the object being grasped, i.e., we consider so-called force closure grasps. Various grasp quality evaluation functions have been proposed in literature, but in practice just a few have been extensively used.

In this sequel we present two algorithms that significantly expedite the computation of two formerly proposed quality metrics. The first was introduced by Ferrari and Canny [5]. It relies on the construction of a convex hull in six dimensions and it is extensively used in practice – in fact it is perhaps the most used. Notwithstanding, this metric has multiple drawbacks. In particular, it is not scale invariant, it does not consider the shape of the object being grasped, and it is somehow too conservative because it considers the set of all possible disturbances, including those that will hardly occur in practice. In the following we refer to this measure as the grasp wrench space (GWS) metric. The second metric we examine was proposed by Strandberg and Wahlberg [6] and, at least in principle, it offers various advantages when compared to [5]. In particular, it considers the shape of the object, it is scale invariant, and it focuses on disturbances that may happen in practice. However, it has been so far rarely used because it is computationally demanding. In the following we refer to this measure as the object wrench space (OWS) metric because it considers only

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