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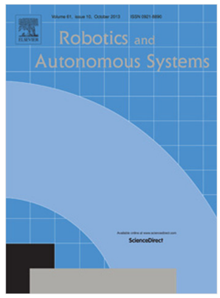

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Iason Sarantopoulos, Zoe Doulgeri

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Human-inspired robotic grasping of flat objects☆

Iason Sarantopoulos[a], Zoe Doulgeri[a]

[a]Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Thessaloniki, 54124 Greece and Information Technologies Institute (ITI) Center of Research and Technology Hellas (CERTH) 57001 Thessaloniki, Greece

Abstract

In this paper, we propose a human-inspired framework for grasping domestic flat objects placed on planar support surfaces. In particular, three grasp strategies are proposed which aim to pinch small flat objects from different scenes. The framework uses representations of the robotic hand, the support surface and the target object which encapsulate rough information for the scene. Furthermore, the strategies exploit the environmental constraint of the support surface by establishing compliant contact with it, which leads to increased robustness against object geometry uncertainties as well as pose estimation errors possibly introduced by the perception system. This is inspired by how humans perform relative grasping tasks with object pose and geometry uncertainties by using compliant contact with the support surfaces. Finally, the strategy selection is determined by a decision making procedure which uses the current scene representation.

Keywords: Human-inspired grasping, environmental constraints, flat objects

1. Introduction

The future service robot's aim is to operate in domestic environments and deal with everyday objects. This means that the robot should be able to grasp, manipulate, place and/or handover domestic objects. Many approaches have been proposed in the last decades towards this goal. In the recent review on grasp synthesis algorithms by Sahbani *et al.* [1], the authors classify the methodologies into *analytical* and *empirical* (or *data-driven*). Analytical approaches consider kinematics and dynamics formulations in order to determine contact points for stable grasps. On the other hand, data-driven approaches focus on techniques that involve classification of different grasps and learning methods that avoid the computation complexity of the analytical ones. While Sahbani *et al.* [1] divide the data-driven approaches based on whether they utilize object features or observation of humans during grasping, Bohg *et al* [2] group them based on their assumptions on the target object, yielding three categories: *known*, *familiar* and *unknown objects*. The grasping approaches for known objects assume the target object has been encountered before and the robot has access to an *experience database* containing exact object models and their associated grasps. The approaches considering familiar objects assume that new encountered objects are similar to old ones and can be grasped in a similar manner, by grouping them together based on common object characteristics. Finally, the approaches considering unknown objects do not assume any kind of prior grasping experience. However, all the above strategies rely on identifying suitable contact geometries assuming free space around the object to plan a stable grasp given a robotic hand. In realistic settings, objects are placed on a planar support surface (table, shelf, the kitchen counter, the floor etc), which when introduced into the grasp-planner's scene is considered a constraint to be avoided. The flatter the object, the more difficult to find a grasp without colliding with the support surface. As a result, grasp planners generally fail to produce a solution in the case of a small or flat object lying on a surface [3]. On the other hand, the remarkable dexterity with which humans manipulate a variety of flat objects stems from strategies that involve contact with the environment. As a precedent, consider the case of the different strategies involved in human grasping of a smartphone, a book or a plate lying on a table. Moreover, recent findings suggest that the utilization of environmental contact compensates for object pose estimation errors. Heinemann *et al.* [4] investigated the human grasping behavior, with respect to their use of contact constraints. The authors conducted experiments in which the artificially vision impaired participants were asked to grasp objects like buttons or pens placed on a tablet device. It was discovered that humans compensated for the uncertainties introduced by impaired vision by using contact with the support surface. Therefore, the need to develop grasp strategies that incorporate contact with the support surfaces is imperative, particularly in the case of flat objects.

Research on robotic grasping has only recently focused on exploiting environmental constraints during grasp synthesis [3–9]. In [7] the authors introduce the concept of *external dexterity*, which denotes the ability for in-hand manipulation using a very simple gripper, by utilizing the motions of the arm, object inertia and external contacts with the environment, while [9] based on this work presents an adaptive controller for pivoting an object. Elliot *et al.* [8] present a learning approach for

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Email addresses: iasons@{auth.gr, iti.gr} (Iason Sarantopoulos), doulgeri@{eng.auth.gr, iti.gr} (Zoe Doulgeri)