# AUTOMATED GRASP PLANNING AND EXECUTION FOR REAL-WORLD OBJECTS USING COMPUTER VISION AND TACTILE PROBING

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## Abstract

This article describes an automated grasping system suitable for complex 2.5D real-world objects (i.e., objects with height < width). The system hardware consists of a robotic manipulator, a three-fingered dexterous hand with a palm-mounted CCD camera, and a PC. The shape of the given object, along with its position and orientation, are not known by the system a priori. A 2D model of the object is first obtained using computer vision. This model, along with height information obtained using online tactile measurements, forms the input to the grasp planner. The planner extends our second-order limited mobility grasping theory to generate optimal immobilizing 2D grasps. Two novel quality metrics are employed in the optimization. The grasp-planning theory is applicable to grasps with three or more fingers. The tactile information is used to extend the grasp to 2.5D objects. We assume that the fingers of the robotic hand will provide an out-of-plane constraint for the object. Experiments are performed on three complex shaped automotive parts using a three-fingered, nine-axis, dexterous hand. The total time for object modelling and grasp planning was under 0.3 s for each part. The parts were successfully grasped and immobilized in all of the tests performed.



## Key Words

Grasp planning, grasp analysis, grasping, second-order immobilization, second-order mobility, dexterous hands, computer vision, tactile probing


## 1. Introduction

An important goal in robotics research today is the ability to grasp objects whose shape is not known a priori. This has application both in service robotics, where many unknown objects are encountered, and in the growing area of rapid-response, small-batch manufacturing of customized products. The ability to grasp requires a method for generating a model of the object online, followed by grasp planning based on this model. The most common way to gain geometric information about an unknown object is through the use of a CCD camera.

In recent years, there has been some investigation into the grasping of objects using visual information. Schrott [1] used visual information to identify the object to be grasped from a known set of objects. Laugier et al. [2] combined visual data with partially known geometric information about the object, as well as the workspace information for the robot, to grasp the objects. Kragic, Miller, and Allen [3] started with a CAD model of the object, used computer vision to find its pose, and then planned and executed the grasp online. In all of these articles the object was at least partially known a priori.

Bendiksen and Hagar [4] as well as Sanz et al. [5] described vision systems that grasp unknown planar objects with a parallel-jaw gripper. Rodrigues, Li, Lee, and Rowland [6, 7] performed the same task using a three-fingered gripper, which acts in a similar manner as a parallel-jaw gripper, that is, it only has two states: open and closed.

Other researchers have dealt with unknown three-dimensional objects. Taylor et al. [8] and Trobina and Leonardis [9] presented visually guided systems that grasped arbitrarily shaped 3D objects from a pile. Davidson and Blake [10] visually planned a 2D "cage" grasp and applied it to 3D objects. All made use of simple two-fingered grippers. Taylor et al. generated a model by performing world motions about the object to determine the most ideal grasp location, whereas Trobina and Leonardis used range sensors to create the 3D model.

Bard et al. [11] and Stansfield [12] both presented a different approach to the problem. They made use of a Salisbury hand, which is a three-fingered device, where each finger has three degrees of freedom. Bard et al. used stereo vision to obtain a 3D model of the unknown part. However, this model was found to be inadequate for successful grasping. Stansfield used a structured lighting vision system to obtain a set of object surface points. Stansfield also employed grasping knowledge obtained from studying the way a human performed the task, in order to improve the system's performance.

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(paper no. 206-2560)