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Automated Modeling and Robotic Grasping of Unknown Three-Dimensional Objects

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Abstract – **This paper describes the development of a novel vision-based modeling and grasping system for three-dimensional (3D) objects whose shape and location are unknown a priori. Our approach integrates online computer vision-based 3D object modeling with online 3D grasp planning and execution. A single wrist-mounted video camera is moved around the stationary object to obtain images from multiple viewpoints. Object silhouettes are extracted from these images and used to form a 3D solid model of the object. To refine the model, the object's top surface is modeled by scanning with a wrist-mounted line laser while recording images. The laser line in each image is used to form a 3D surface model that is combined with the silhouette result. The grasp planning algorithm is designed for the parallel-jaw grippers that are commonly used in industry. The algorithm analyses the solid model, generates a robust force closure grasp, and outputs the required gripper position and orientation for grasping the object. The robot then automatically picks up the object. Experiments are performed with two real-world 3D objects, a metal bracket and a hex nut. The shape, position and orientation of the objects are not known by the system a priori. The time required to compute an object model and plan a grasp was less than 4 s for each object. The experimental results demonstrate that the automated grasping system can obtain suitable models and generate successful grasps, even when the objects are not lying parallel to the supporting table.**

I. Introduction

Typically, for robotic grasping to be successful the shape and location of the object must be known in advance. This lack of adaptability has two main disadvantages. First, expensive fixtures or other devices must be used to position and orient the object prior to grasping. Second, the robot is limited to objects whose shape is already known. A vision-guided grasping system that could adjust to the position, orientation and shape of the object would provide the needed adaptability. Such a system would be useful in both manufacturing and service applications of robots. Robots equipped with vision systems capable of grasping objects whose planar shape and location are unknown have existed for many years (e.g. [1]). However, the automated grasping of three-dimensional (3D) objects whose shape and location are unknown *a priori* remains a challenging and unsolved problem, and is the subject of this paper. Its solution necessitates online object modeling, grasp planning and grasp execution. Note that this is distinct from the problem of recognizing the object from a predefined set or database of known objects and then grasping it. Stansfield [2] presented a system for grasping 3D objects with unknown geometry using a Salisbury robotic hand. Each object was first placed on a motorized table. The object was then rotated and translated under a laser scanner to generate a set of 3D points. These were combined to form a 3D model. The model formed the input to an expert system that planned the grasp. Experimental results were presented for several objects. A system using a parallel-jaw gripper and machine vision intended for picking an object from the top of a pile was described by Taylor, Blake and Cox [3]. They used a wrist-mounted camera to first scan the pile for the highest object. They described a method for planning a grasp for this object based on images from several viewpoints. However, the only experimental grasping results they included were for a single object (a potato) located on a table. The system presented by Trobina and Leonardis [4] used two range sensors to model groups of objects. The models, consisting of planar patches, were used to plan grasps for a parallel-jaw gripper. The tallest object was picked up and removed first, a new 3D model constructed, and the process repeated until all objects had been removed. Only one experimental result for a set of household objects (milk carton, coffee cup, etc.) was included. Namiki *et al.* [5] presented a system for high speed grasping using visual and force feedback with a 1 ms sampling rate. Their system was able to grasp a moving object in about 0.5 s, but the robotic hand they used had to be pre-shaped according to the expected shape of the object. Only rectangular block and spherical shapes were considered. The object motion was also limited to a plane and the final position of the object within the hand could not be determined. A system combining a grasping simulator with a real-time visual tracking system was described by Kragic, Miller and Allen in [6]. The tracking system could accurately estimate the 3D pose of the object while the simulator was used to generate a suitable grasp. However, both the tracking system and grasping simulator required a predefined CAD model of the object in order to function. A humanoid robot equipped with a stereoscopic light stripe scanner and a prosthetic hand was presented by Taylor and Kleeman [7]. Their robot could reliably track objects through clutter by employing color, texture and edge information. It successfully located and picked up a yellow box, given only the information that the object was yellow

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