Gripper Design and Grasp Planning for Fixtureless Assembly

Gary M. Bone* and Lucian Balan
Department of Mechanical Engineering
McMaster University
Hamilton, Ontario, Canada, L8S 4L7.

*Email: gary@mcmaster.ca

Abstract

Dedicated fixtures are costly and inflexible. The goal of fixtureless assembly is to replace assembly fixtures with sensor-guided robots equipped with flexible grippers. This, in turn, requires the development of automated grasp planning strategies, and grippers with the flexibility to pick up and immobilize a wide range a object sizes and shapes. In this paper, an efficient grasp planning method, the design of a highly flexible gripper, and initial results on the automated design of minimum complexity grippers are presented. The grasp planning strategy is suitable for 2.5 D objects and plans grasps which immobilize the object without the use of friction or large clamping forces. The flexible gripper design features three fingers with a total of nine degrees-of-freedom and a 400 mm dia. X 75 mm deep workspace. A novel hybrid parallel-serial mechanism, and use of pneumatic servo actuators, enable it to achieve high stiffness with low mass. The gripper is capable of grasping of wide range of object shapes. For applications requiring less flexibility, a procedure is presented for automatically designing a modified parallel-jaw gripper capable of grasping a given set of parts. Results are shown for a set of three objects, including an automotive waterpump housing.

Keywords: automated assembly, fixturing, fixtureless assembly, grasp planning, gripper design.

1. Introduction

Assembly operations in many industries make extensive use of dedicated fixtures. These fixtures are part specific, and therefore must be modified or replaced when model changes are introduced. The cost of redesigning, manufacturing and installing these fixtures is substantial (on the order of $100 million/plant/year for automotive manufacturers [1]) and would be significantly reduced if a more flexible alternative was developed.

As the name suggests, the goal of fixtureless assembly is to eliminate use of costly, inflexible, dedicated fixtures. The development of flexible alternatives to fixtures, and to automotive sheet metal fixtures in particular, has received little attention in the literature. Flex-tool, developed by FANUC Robotics [2] from 1992 to 1994, is a system of several "positioners" (small, simplified, robot arms) with locators or clamps mounted on them. While this system offers much greater flexibility than traditional fixtures, it requires "common datum patches" on the parts, limiting its flexibility. Each positioner may only position one type of clamp or locator, which further limits the system's use. Nissan's Intelligent Body Assembly System (IBAS) [3] includes flexible fixturing machines consisting of as many as 35 positioning robots and 16 welding robots. Each machine can only assemble one portion of the car, e.g. the engine compartment, and therefore does not have true assembly flexibility. In another related work, Mills [1] proposed a discontinous control approach to control the mating of sheet metal parts in a preliminary robotic assembly system. Fender-like parts were successfully mated using their control scheme.

The long term goal of our work is to replace assembly fixtures with sensor-guided robots equipped with flexible grippers. In this paper, we describe an efficient grasp planning method, the design of a highly flexible gripper, and initial results on the automated design of minimum complexity grippers.