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Gripper Design and Grasp Planning for Fixtureless Assembly

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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 per plant per 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 in particular, automotive sheet metal fixtures, has received little attention in the literature. Flextool, 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, such as the engine compartment, and therefore, does not have true assembly flexibility. In another related work, Mills [1] proposed a discontinuous control approach to control the mating of sheet metal parts in a preliminary robotic assembly system. Fender-like parts were successfully mated using the control scheme.

The long-term goal of our work is to replace assembly fixtures with sensor-guided robots equipped with flexible grippers. In this article, 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.

LMG Grasp-Planning Strategy

The grasping strategy is an important determinant of gripper design. The design ultimately depends on the object shape and type of grasp desired. For generic manufacturing applications, it is important that the object is held precisely and securely, and that the surfaces to be assembled (or treated in some other fashion) remain accessible (they are not covered by the gripper's fingers). For this reason, our grasping strategy will employ "fingertip grasps" rather than "enveloping grasps," which involve wrapping the gripper fingers around the object. Use of fingertip grasps provides both precision and high accessibility, and will provide good grasp security if the contact points are properly located and the fingers are sufficiently stiff. With fingertip grasps, the gripper design problem reduces to the design of the fingertips and the means to control them.

A grasp-planning strategy is required to properly locate the contact points and also impacts