PERGAMON

Robotics and Computer Integrated Manufacturing 19 (2003) 79–87

Robotics and Computer Integrated Manufacturing

www.elsevier.com/locate/rcim

Vision-guided fixtureless assembly of automotive components

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Abstract

Assembly operations in many industries make extensive use of fixtures that are costly and inflexible. The goal of "robotic fixtureless assembly" (RFA) is to replace these fixtures with sensor-guided robots. In this paper, the development of a vision-guided RFA workcell for automotive components is described. Each robot is equipped with a multiple degree-of-freedom programmable gripper, allowing it to hold a wide range of part shapes without tool changing. A 2D computer vision is used to achieve part pickup which is robust to positioning errors. A novel 3D computer vision system is used to align the parts prior to joining them. The actions of the workcell devices are coordinated using a flexible distributed object-oriented approach. Experimental results are presented for the RFA of four automotive body components.

Keywords: Automated assembly; Automotive assembly; Computer vision; CORBRA; Fixtureless assembly; Pose measurement; Programmable fixture; Serro gripper; 3D Vision; Universal gripper; Vision-guided robotics

1. Introduction

Assembly operations in many industries make extensive use of dedicated fixtures to hold and align parts before they are joined together. These fixtures are part specific, and therefore must be modified or replaced when product design changes are introduced. The cost of redesigning, manufacturing and installing these fixtures is substantial (e.g. on the order of $100 million/plant/year for automotive manufacturers). The goal of "robotic fixtureless assembly" (RFA) is to eliminate the use of dedicated fixtures. This involves replacing the fixtures with sensor-guided robots equipped with programmable grippers. Reconfiguration for new products then involves only a software change (as opposed to changing the fixturing hardware). This would allow rapid product changeover in response to customer demand. Several products could also be made using a single RFA workcell, saving the costs associated with multiple installations. Our interest is limited to the RFA of rigid parts.

The RFA concept was first introduced in the literature by Hoska in 1988 [1]. He described the advantages of RFA, some of the technical challenges involved and discussed potential solutions. Ro et al. [2] presented an approach for finding optimal kinematic postures for two robots performing RFA. They used velocity and force ellipsoids to develop a suitable performance criterion. Their algorithm was demonstrated for two 2D robots using computer simulations. Mills and his group have studied the control issues involved in the RFA of flexible parts [3,4]. In [3], they developed a dynamic model of the parts using finite element analysis and Guyan reduction. Combining this with a dynamic model of the two robots allowed them to investigate several control methods. Simulation results revealed that standard control methods could achieve stable part mating results. In [4], they proposed a control algorithm, which does not require measurements of the part deflections. Successful experimental mating control results are presented for a pair of flexible, fender-like parts. Plut and Bone [5,6] presented a grasp planning strategy for RFA. This strategy produces grasps, which immobilize objects kinematically, requiring minimal friction or clamping forces. The grasping points are also planned such that initial positioning errors are corrected by the grasping action. In experiments performed on two automotive parts, the standard deviation of the part location was reduced from 0.43 mm (before grasping) to 0.01 mm (after grasping). Choi [7] presented dynamic models of two robots performing a

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PII: S0736-5845(02)00064-9