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3-D Flexible Fixturing Using a Multi-Degree of Freedom Gripper for Robotic Fixtureless Assembly

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Abstract

A novel grasping strategy and gripper for fixturing in 3-D is presented for the robotic fixtureless assembly application. The goal of the strategy is to accurately immobilise a part in the presence of initial robot and part positioning errors. The grasping strategy expands a previously developed 2-D theory into 3-D and is implemented on two automotive parts using a multi-degree of freedom gripper. The gripper is able to fixture a variety of parts and the only change is reconfiguration of the computer controlled axes. To fixture a sheet metal part, the fingers are placed within holes of the part and moved until the desired set of contact locations is achieved. The fingers are grooved at fixed angles such that the edge of the sheet metal part can be held within the grooves. Three fingers and six frictionless point contacts are used for each part. A computer algorithm is described that solves for suitable contact locations based on the part geometry. The algorithm was implemented and tested on two Buick sheet metal parts from the front fender assembly. Twenty five trials were performed for each grasp. The standard deviation of the part location prior to being grasped was 0.43 mm. After being grasped, this was reduced to 0.01 mm.

1 Introduction

Current single purpose fixtures are not suitable to modern manufacturing needs. When a new model is designed, new fixtures must also be designed. These new fixtures are expensive and the time delay to make the them poses two problems. The 4 to 6 month lag to build the fixture compromises the competitiveness of the manufacturer and the installation of the new fixture represents costly down time in the plant. Fixtures are used extensively in automotive and aircraft assembly for holding sheet metal parts during welding and riveting. A recent potential solution to this problem is the use of two robots to assemble and a third robot to join the parts without conventional fixtures or physical manpower. The fixturing would be accomplished by a versatile gripper on the end of the robot. When parts are changed for a new model, the only change should be computer controlled reconfiguration of the gripper. This approach is known as Robotic Fixtureless Assembly (RFA) [3]. RFA is expected to reduce the re-tooling costs by 80% [4].

The issue in RFA addressed in this paper is fixturing of different parts using a multi-degree of freedom gripper. The fixturing will be performed in 3-D. Since sheet metal parts often have very smooth oily surfaces, frictional contacts cannot be relied upon for fixturing applications. In this work, the contacts between the fingers and the part are modeled as frictionless point contacts (FPCs). FPC's have the additional advantage of being able to slide to their desired locations.

As in conventional fixturing, the first goal is to locate the part accurately. Typically an accuracy of ± 0.1 mm is required for RFA [4]. Initial errors due to robot and part positioning must be overcome to achieve this goal. The second goal is immobilisation of the part at its desired location. To achieve these goals, a suitable fixturing strategy must firstly be developed.

Many form closure models exist that determine the number and location of FPC's required to immobilise an object in 3-D [7]. Rimon and Burdick [6] extended the concept of immobilisation from form closure (a first order mobility theory) to include second order immobility. They derived new lower bounds on the number of FPCs required to immobilise objects. Conventional fixture designers rely on a pseudo form closure approach known as the "3-2-1" rule [2]. Asada [1] introduced an approach for accurately locating and holding parts using reconfigurable fixtures. The contact points are selected such that the part's position relative to the fixture has a unique solution when all of the points are touching. Known as deterministic positioning, this approach is capable of significantly reducing the initial part placement errors. The final accuracy is a function of the accuracy of the part at the contact points, just as with conventional fixturing.

Previously developed fixturing methods can be used to determine the number and locations of the contacts but disregard how and if the contact locations can be reached. In particular they often do not account for the effects of initial robot and part positioning errors,

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