Experiments Comparing Precision of Stereo-Vision Approaches for Control of an Industrial Manipulator

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1 Motivation, Problem Statement, Related Work

Despite years of research in the area of robotics, the vast majority of industrial robots are still used in "teach-repeat" mode. This requires that the workpiece be in exactly the same position and orientation every time. In many high-volume robotics applications, this is not a problem, since the parts are likely to be fixtured anyway. However, in small to medium lot applications, this can be a significant limitation. The motivation for this project was a corporation who wanted to explore the use of visual control of a manipulator to allow for automated teaching of robot tasks for parts that are run in small lot sizes.

Since the 1970s, researchers have been proposing ways to use vision in order to solve this problem. While the purpose of this paper is not to provide a complete review of vision-based robotic manipulation, an excellent overview of early work is found in [1]. There has been success in the application of such technologies, especially in 2-D and 2.5-D problems [2]. Despite the fact that the theory for the solution of this problem has been established, there are limited implementations of full 3-D applications. Basically, the reasons for this come down to "the devil is in the details" and, in real 3-D applications, the accuracy, robustness, and cost-effectiveness of vision-based systems have been insufficient to justify widespread use.

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A variety of efforts have been put forth to solve the problem of vision-based robotic manipulation. Visual Servoing offers promise by "closing the loop" in the image plane [3]. However, in many assembly tasks, the robot end effector obscures the target when it gets close to task completion. Several methods have been proposed to get past this limitation, such as outfitting both the robot and the workpiece with fiducials that remain visible [4], or "eye-in-hand" in cases where it is possible to place the camera(s) in the robot end effector. Another limitation of visual servoing is that in general it provides the least accuracy in the direction of the focal axis. Camera Space Manipulation [5][6] offers an alternative methodology and has been shown to allow completion of high-precision 3-D tasks. Unfortunately, this method does not allow standard stereo cameras to be used, as it requires widely separated and highly vergent cameras and utilizes the simplified orthographic model (though later work created accuracy similar to the pinhole model) [7].

The Mars Exploration Rovers used stereo vision with calibration for placing instruments on rock and soil targets [8], but this showed some limitations in accuracy [9]. Recently, in space robotics applications, two additional approaches have been offered, HIPS [9] and AGATE [10][11]. Both of these approaches have shown promise on space-related platforms to produce high-precision, vision-based manipulation using stereo cameras, with an application of instrument placement. These papers also reported large numbers of experiments. In particular, [9] showed the improved accuracy using HIPS compared to precalibrated stereo on NASA testbeds. However, these testbeds typically have inaccurate kinematics (backlash, inconsistent zero offsets, lack of rigidity, etc.).

2 Technical Approach

In response to a request from a local manufacturer, several of the authors were involved in a project to use computer vision to automate the teaching of a robot task for parts with small lot sizes. The details of that task are found in [12]. While the corporation was pleased with the results of the project, the accuracy obtained was not sufficient for all of their parts. As such, the authors have begun a detailed investigation of the accuracy obtained, and how that compares to other approaches. It should be noted that the industry-focus of this project has influenced the technical approach.

The goal of this paper is to answer the question of whether techniques such as AGATE can create significant improvement in accuracy when applied to an industrial robot by using local data to modify the parameters of the camera-robot model. Also, while AGATE was developed for mobile manipulation (as it can control the mobile base and the manipulator relative to a visual target), this paper will use AGATE techniques for a fixed-base manipulator. The paper further includes the first direct comparison of AGATE with HIPS. Future work will compare these methods directly to visual servoing and traditional camera calibration techniques.