Vision Based Manipulation of a Regular Shaped Object

Sachin Kansal, Sudipto Mukherjee

Mechanical Engineering Department, IIT Delhi, New Delhi 110016, India

Abstract

This paper proposes to attempt is to manipulate an object by a set of three contacts (fingers) i.e. three end effectors of the delta robots. As the point of contact with the finger and object changes dynamically, making the problem to have a large degree of variability. This proposal is limited to direct feedback of the object position with respect to the world coordinates and interfacing with the delta robot controlling in real time environment. Detection of markers by three cameras is achieved using ArUco augmented reality library. Experimental results are presented to support the approach in this paper.

Keywords: Augmented Reality; Manipulation; Delta robot; Multiple View

1. Introduction

The manipulation based on vision refers to the use of computer vision with one or more camera data in order to manipulate the object using the delta robot. Visual servo loop is also implemented to control the motion of a delta robot. Vision based manipulation is a mature research field. As over the last few years, various vision based manipulation works have been published. Antonio Morales et al. implemented a strategy for computation of vision based three finger grasps taking as input an image of the object to be grasped. Strategy is described in three steps: first, extraction of grasp regions; second, region suitability test; last, determination of grasp points. It computes outer and inner contours for generating grasps within minimum time. Anton Nikolaev et al. presented a transparent gripper for robot vision that allow vision sensors to take images of an object without occlusion. Image shift caused by refraction is compensated by the presented algorithms. The transparent gripper has two applications: first, it improves the perceptual ability of the robot system and second, task of automatic generating of 3D object models. Hasimah Ali et al. presented development and design of the gripper which is smart and it comprise of vision sensor. In this approach integration of vision sensor and applying controlling techniques, so that in order to grasp the object without error by appropriate force. This system incorporates vision sensor for object detection. In the first phase, the smart gripper is set to the initial position. The proposed gripper in this paper has a limitation of lifting and grasping the object that have different weights. Goro Obinata et al. presented a method for the estimation of contact state of objects having varying shape using
tactile sensor which is based on a vision. Estimating the position of the object is achieved by contacting dots. Translational displacement of the object corresponds to the contact dots displacement. In this approach the sensor does not give enough information about the orientation of the object. In this approach use of an LED light, CCD camera, touch pad and transparent acrylic plate are used.

Robert Haschke et al.\textsuperscript{5} presented a control strategy in which estimation of the contact point locations is achieved. In this paper use of tactile sensor has been implemented. Object manipulation has been achieved using two stage process, i.e. on the first stage, local manipulation controller is achieved as in this stage object moves in a small amount. In the second stage global re-grasp planning using finite state machine (FSM) is performed. In the global planning state definition and the actions which is to be performed has been designed. The validation of the experiments is performed using Vortex, a physics engine.

Mohd. Suhaib et al.\textsuperscript{6} presented dexterous manipulation to control the robot’s finger to generate the rotational motion using a sphere as manipulation object. Keeping the limitation that fingers ordering around the sphere edge should not change during manipulation. In this paper, grasp stability and equilibrating force analysis has been performed. They have used IK solver of 3ds max. The coefficient friction assumed 0.3 for all fingers.

Augmented Reality\textsuperscript{7,8,9,10,11} is a technology that supplemented real world environment of the computer generated objects/elements. The key challenge in this field is tracking and registration of the object. Registration is the proper alignment of the virtual objects in the real world. Occlusion is also the major concern as when tracking is performed, determination of surface which may not visible to the camera viewpoint is also taken care of. It describes the manufacturing, defense, entertainment, path planning has been explored.

The paper is organized as follows. Section A briefly describes the method of the framework. Section B depicts the Camera calibration, Computation of position and orientation wrt to the fixed frame, inverse kinematics of delta robot.

\subsection*{1.1. Method Framework}

The basic problem being attempted to manipulate a cube by a set of three contacts (fingers) i.e. three end effector of the delta robots. The point of contact on the finger and object changes dynamically, making the problem to have a large degree of variability. Practically it poses challenges in robot force allocation, control strategies, motion planning and direct feedback of the object position. The system architecture comprises of vision module, hardware interface module, delta robot and the dynamic analyzing software in order to predict the nature of the object in offline. So, the synchronization of all the modules in an effective manner in order to do the manipulation is required. In the experimental setup as shown below in Figure 1, three Delta robots are arranged symmetrically along the vertices of an equilateral triangle. Collaborative manipulation has to be done to orient an object (cube) in space maintaining positive contact force. Interfacing with the delta robot for controlling in real time environment using Arduino Mega 2560 and MD22 H bridge driver integrated circuit.

![Fig. 1: Experimental Setup](image-url)
triangle. In the experimental setup augmented reality library is being used. Euler angle computation is performed in order to validate the angle variation wrt each axis i.e \((\Theta, \phi, \psi)\).

Given the position and orientation of the cube, we will feed the position parameter into the controller. The controller is having the inverse kinematics module within it for each delta robot respectively. So, we have three \(3 \times 1\) position vector and correspondingly three \(3 \times 3\) rotation vectors. In the experimental setup, implementation of specrol 601HE-0000 encoder is also performed in order to have the feedback of angles from each of the deltas. This feedback is used for the correction of angles and getting the corresponding voltage by the calibration and conversion process. Finally, we feed the correct values of angles to the delta robot in order to have minimum error for manipulation. We do not encounter collision avoidance algorithm between the delta robots.

1.2. Camera Calibration and Synchronization

For camera calibration have taken set of images by changing the pose of the chessboard from the fixed Basler camera. Initially identifying the origin as marked \((0, 0)\) along with Axis direction in the figure 2(a). In Re-projection of the image points 0.28 pixel mean error is encountered as shown in figure 2(b). After calibration intrinsic parameters are calculated and give input to the augmented reality VS C++ application as .Yml file. Camera synchronization using software based methods implemented in order to track the cube using the three basler cameras in a real time environment. As the object is manipulated by the three end effector of the delta robot. With the camera synchronization, we are able to get the position and orientation of the object using three cameras with respect to the fixed base frame as discussed in the next section.

![Fig. 2: Chessboard point detection](image)

1.3. Computation of position and Rotation vectors using Augmented Reality for each of the face of the cube captured by three Cameras

The process of adding the virtual information to the images is termed as Augmented reality. We use the marker to calculate the extrinsic parameter of the camera. In order to render in the 3D information knowing where is the origin of the world reference system.

After the calibration of three cameras and providing intrinsic.yml file for each camera. Detection of the marker has been performed in real time. Detection of four sides of the marker has been computed. Then we compute the position vector size of \(3 \times 1\) and rotation vector size of \(3 \times 3\) of each face of the cube with respect to the respective camera coordinate system.

We track the cube using the basler scout camera which comprises of GigE vision and operate at a rate of 30 fps. The input image from first view is given below in Figure 4. The position of the cube with respect to the world coordinates system are shown in Figure 3.
1.4. Inverse Kinematic Analysis of a Delta Robot

In this section we discussed the Inverse kinematics analysis of a Delta Robot and dynamic analysis of a cube given below.

Given the target position of the end effector to catch the cube with calculated coordinates (X, Y, Z). The calculation is required for the corresponding angles of each of the three arms (joint angles) to set motors (and, thereby, the end effector) in proper position for picking. Inverse kinematics analysis of the delta robot as three parallel kinematics chains, each chain containing one actuated revolute joint connected to the base platform, is needed. Doing inverse kinematics of each of the delta robot, i.e. for each end effector of the delta robot gripping the cube we perform the
inverse kinematics in order to have the three joint angles of each of the three delta robots respectively, with respect to the fixed coordinate system.

Fig. 5: Inverse Kinematic Solution of Delta Robot with Matlab Simulation

2. Conclusion

The capabilities of the manipulation of the cube using multiple fixed camera approach are introduced in this paper. The method framework gives a comparative study of the multiple cameras used for the vision based manipulation with the help of delta robots. In this paper hardware implementation of the delta robot with inverse kinematics solution of the delta robots are discussed.

3. Acknowledgment

The authors would like to thank Mr. Dharmender Jaitly, Mr. Anil Kumar Sharma, Mr. Mohd. Zabair, Mr. Paramanand Nandihal, Mechatronics Lab, Mechanical Engineering Department, IIT Delhi for his support.

References