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Control Technique for Parallel Manipulator using PID

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Abstract— **Parallel manipulators are quite efficient when compared with serial manipulators since it can be used in high speed applications. But control of parallel manipulator is quite difficult. In this paper, a adaptive PID control of parallel manipulator is done and its performance is verified. The control of parallel manipulator using PID proved to be quite efficient when compared with other existing control technique. With PID control the parallel manipulator is able to trace along the desired trajectory without any deviation. Here the manipulator was independent of the operational change and also is able consider the system dynamics .Also this method has a advantage of having low error rate .Here delta parallel manipulator is used to control scheme efficiency. Delta parallel manipulator is realized based on sim mechanics model.**

Keywords – Parallel manipulators, PID, sim mechanics, DOF

I. INTRODUCTION

The serial manipulator has numerous merits when compared their counterpart serial manipulators. The parallel manipulator can be used for high speed application and also they have a reduced error rate when compared with serial manipulator. The comparison between serial and parallel manipulators is discussed in [1] and it enlisted the numerous advantages of parallel manipulators over serial manipulators. This work makes various classification of parallel manipulator and it also discusses applications of the parallel manipulators. Here the Symmetrical, Planar, Spherical, and Spatial are various classification of the parallel manipulator. Also various types of applications such as industrial, space, medical are also discussed.

Even though the parallel manipulators have many advantages over serial manipulators they have main drawback called singularity. The concept of singularity in workspace was discussed in [2], [3], [4]. Different kinds of singularities is discussed in [3]. Here classification of singularities is made based on the properties of the Jacobian matrices of the chain. A differential geometric analysis of kinematic singularities for closed loop kinematic chain mechanisms is discussed in [4]. The work [5] discusses dynamic model of parallel manipulators. Using the Lagrange–D'Alembert formulation it proposed a method for calculation of inverse kinematics. This work discusses four basic control algorithms namely, a joint-space proportional derivative (PD) control, a PD control in generalized coordinates, an augmented PD control, and a computed-torque control, are discussed.


Fig 1.1Views Of Parallel Manipulator

The work [6] presents a dynamics method to be applied to redundant parallel manipulators. A technique for calculating the inverse dynamics of closed-link mechanisms using the d'Alembert's principle was presented. The work [7] presents redundant actuation was used to eliminate undesired singularity effects in parallel manipulators using method in [6]. Actuation redundancy was proposed in this work. Three kinds of redundant methods are developed and their advantages were discussed. Numerous merits of parallel manipulator using actuation redundancy was presented. Stiffness is increased by actuation redundancy. Payload and acceleration that can be handled by the parallel manipulators is improved by actuation redundancy. Also with actuation redundancy improvement in force transmission can be obtained. In the experiments, it concentrated on the control of redundantly actuated parallel mechanisms. In [8], actually compares a proportional-integral-differential (PID), an augmented proportional-derivative (PD) and a computed torque controller and control schemes were evaluated based on the experimental result. Computed. Self-gain tuning computed torque controller based control scheme was proposed in [9]. The conventional Computed Torque Control law is a linear control method to combine the PD control term and the feedback dynamic compensation term. This method proposes a CTC method for parallel manipulators. Reduced tracking errors due to nonlinear factors such as modeling error and friction in the dynamic model of the parallel manipulators are the demerits of the conventional CTC method. Thus, a new algorithms are used to tune the PD gains in the CTC method. Intelligent methods were used to optimize the PD gains earlier in computed torque controller. It is not easy to carry out these types of controller due to complicated structure and innumerable calculations .Therefore in order to improve the control performance an online self-gain tuning method using neural networks was proposed. This method was simple and is effective when compared with other tuning methods. Also, provided a good tracking trajectory.

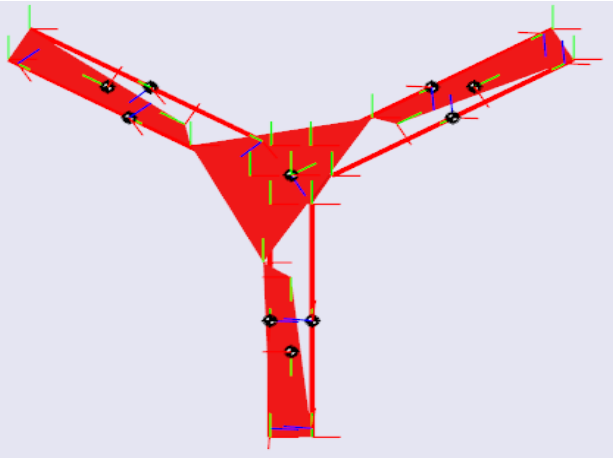
In [10], redundantly actuated parallel manipulator was used to test an proposed adaptive controller in task space that included adaptive dynamics compensation, adaptive friction compensation, and error elimination items. Parameter adaptation law was obtained using Gradient descent algorithm. Trajectory tracking of a 2-DOF redundantly actuated parallel manipulator was obtained by nonlinear adaptive (NA) controller in the task space . The dynamic model with nonlinear friction is established in the task space for the parallel manipulator, and the linear parameterization expression of the dynamic model is formulated. A new control law including adaptive dynamics compensation, adaptive friction compensation and error elimination items was designed based on the dynamic model. The NA controller is implemented in the trajectory tracking experiments of an actual 2-DOF redundantly actuated parallel manipulator, and the experiment results are compared with the APD controller.

A design of a robust output feedback controller for trajectory control of n-link robot manipulators was discussed in [11] . Quadratic performance index was used to find Joint velocities. Performance of the proposed method was verifies based on simulation of a 2-link robot manipulator.

II. DELTA PARALLEL MANIPULATOR

A parallel manipulator supports a single platform, or end-effector using several computer-controlled serial chains . Closed loop kinematic chains are used to characterize parallel manipulators. Parallel manipulators have numerous advantages in terms of accuracy ,rigidity and ability to manipulate heavy loads when compared to serial manipulators have open ended structure. Therefore, they have been used especially automobile and machine-tool industries.

A delta manipulator having 3 degree of freedom and 3 actuator is used here It consists of three parallel kinematic chains which connects the moving platform to base. The joints are activated by actuators in the base platform in each chain. Delta manipulators are being used . for many different applications such as in manufacturing of solar panels use Delta robots to place photovoltaic silicon wafers onto glass substrates. They are also used to snap together several plastic parts and place the finished assembly into a box.



II. PID CONTROLLER

In PID controller the signal generated by the PID controller is directly proportional to the error sensed by the sensor. The difference between a desired set point and a measured process variable is taken as error value in PID controller.The PID controller does not require prior knowledge of the parallel manipulator and are therefore most commonly used in industries.

The classic PID takes the form as shown below :

$$u_i = K_P e_i + K_i \int e_i \, dt + K_d \frac{de_i}{dt}$$

K_P, K_i, K_d are PID controller gains.

III. METHODOLOGY

There are numerous control schemes for the control of the parallel manipulators, but none of the control scheme considered the operational condition change problem. Here a dual-space adaptive controller is proposed. This control scheme not only is able to maintain its good performance in both scenarios without any need of manual readjustment of its parameters but also provides a better performance even when this last one is best configured for each specific case.

A. Control Law

The control law of the adaptive control of parallel manipulator is given by

$\tau = H^T M_{tot} X_d + I_{tot} q_d + K_p e_j + K_d \dot{e}_j$

in operational space it can be written as

$F = Y\theta + K_{pc} e_c + K_{dc} \dot{e}_c$

where K_{pc} and K_{dc} are positive feedback gains

B. Trajectory Generation

The desired trajectory for the experiment is described as follows

x_d = K 0.115sin(2Πft)

y_d = K 0.115sin(2Πft + $\frac{\Pi}{2}$)

where f is the frequency of circular movement.

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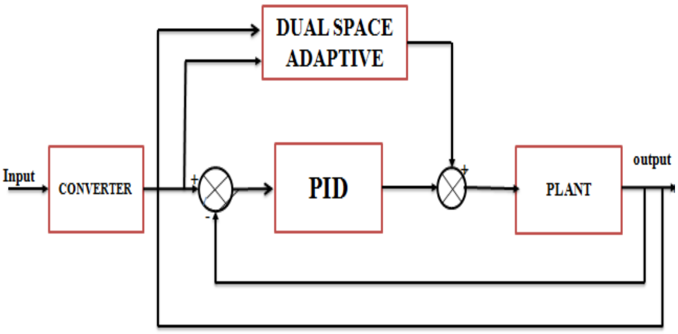

Fig 3.1 Simplified block diagram

The fig 3.1 shows a simplified block diagram of the proposed method. Here a trajectory is given as input but since only the joint positions are measured the trajectory is converted into joint space using a inverse kinematics which is shown here as a converter block and joint tracking error is computed. But the joint tracking error cannot be directly given as input to the PID controller therefore it is converted into cartesian space. The trajectory along with joint tracking error is given as input to the adaptive scheme based on which the adaptive scheme generates an output. The output of the adaptive scheme along with PID output act as control signal for the manipulator and desired trajectory is maintained.

The parameters that is to be given for the PID is important. The value of the PID gain that is during the experiment is given in following table

K_p	K_i	K_d
4000	500	50

IV. EXPERIMENTAL RESULTS

In this section experimental results obtained with MATLAB simulation during the verification of the adaptive control scheme on delta parallel manipulator is discussed. Here a PID controller is used to control the parallel manipulator. The control of the parallel manipulator using PID controller along with the adaptive scheme is found to be quite efficient as the manipulator is able to trace along the desired trajectory. For checking the effectiveness of the proposed control scheme a spiral trajectory is given as the desired trajectory and the proposed method proved to be quite efficient when compared with the various existing methods. Fig 4.1 and fig 4.2 shows the desired trajectory and actual trajectory traced by the manipulator.

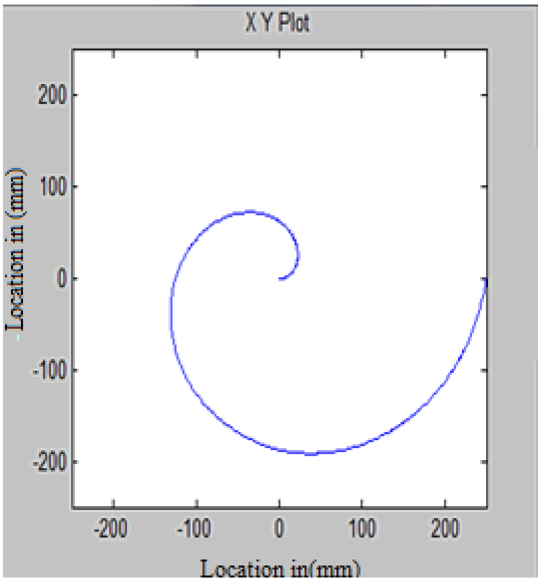

Fig 4.1Desired Trajectory

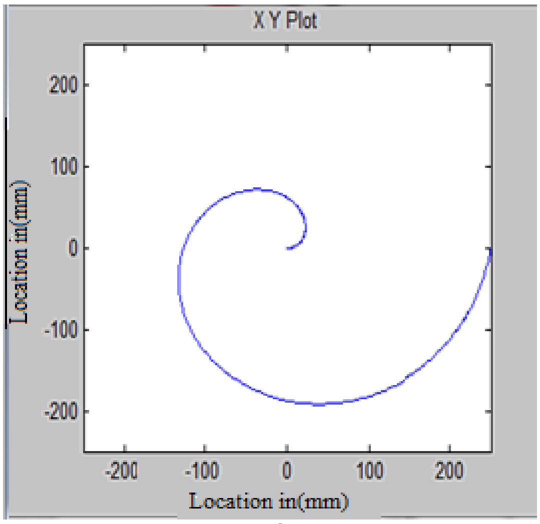

Fig 4.2 Actual Trajectory

From the simulation result it is clear that the desired and the actual trajectories are almost the same and that the error rate is low.The control scheme is quite robust since it can maintain both the smoothness and performance of closed loop system with respect to tracking as well as control input despite oscillation in controller parameter. The decrease in the oscillation may result in the increased performance of the adaptive control scheme.

The 3D view of the actuator is shown in the fig 4.3. The 3D simulation actually depicts the position of the actuators, that is the trajectory traced in x,y and z axes.

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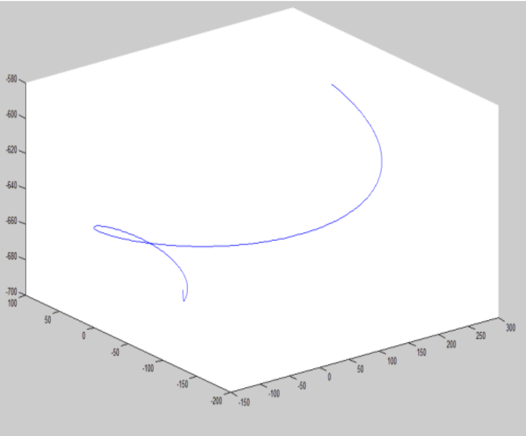

Fig 4.3 3D View Of Actuator Position

The force applied to each actuator is the sum of the adaptive scheme output along with the output of PID controller. The force applied to each actuators in the parallel manipulator is shown in fig 4.4.

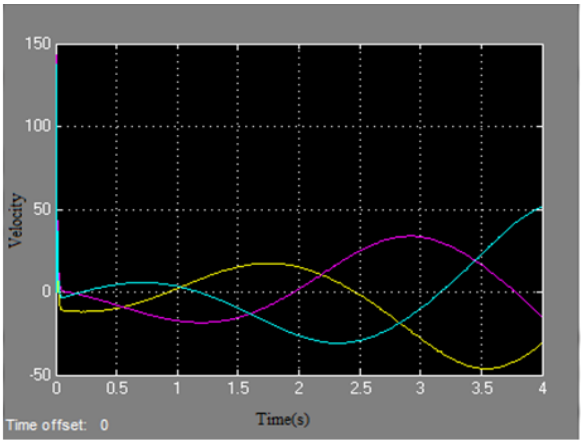

Fig 4.4 Force Applied On Three Actuators

CONCLUSION

Here a design technique for adaptive control of the parallel manipulator is proposed. A PID controller is used to control the parallel manipulator. The adaptive control method is verified on 3 DOF delta parallel manipulator which is realised using sim mechanics model. Simulation result were analyzed and it can be seen that the adaptive control technique is quiet efficient since it is able to trace along the desired trajectory and is not deviating when compared to existing methods.

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