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A Modified Auto-tuned PID controller for Robotic ARM Control

Deepti Rajpoot[1], Devendra Dohare[2]

PG Student [I&C], Dept. of EE, MPCT, Gwalior, MP, India[1]

Assistant professor, Dept. of EE, MPCT, Gwalior, MP, India[2]

ABSTRACT: Point-to-point robotic arm has been used in manufacturing industry to assist company in increasing its production rate. However, the biggest concern in robotic arm is the accuracy for the robot to complete the task of pick-and- place of an object which is dependent on the designed controller. This study investigates the accuracy of the 6 degrees of freedom (DOF) robotic arm model with PID controller. The forward kinematic is analysed systematically in order to determine the required movements for each of the robotic arm joint for its desired operations. The objective of this paper is to simulate the movements of the robotic arm with and without controller by utilizing MATLAB GUI, a microcontroller and servo motors in order to demonstrate the effectiveness of the system. Performance comparison of the robotic arm in completing the pick-and-place task with and without auto-tuned PID is presented in this paper. The preliminary results showed that the difference errors between the desired angular displacement of with and without controller has been improved.

KEYWORDS: kinematics analysis, Robotic arm, MATLAB,PID controller, Auto-tuning.

I.INTRODUCTION

PID controllers form the great majority of the controllers that are used in practical applications [1], [2]. Recent research on systematic PID controller design have focused on finding the set of. stabilizing PID parameters rather than providing a “clear cut” tuning rule [3], [4], [5]. Such an approach is usually very practical as it provides enough design freedom to be used in the implementation phase (see, for example, [6]).
One intricacy of such an approach is that it is not possible to guarantee the transient response performance of the closed-loop system. Nevertheless, it is long known that it is possible to shape the time-response of a system by placing the closed-loop system poles to suitable locations [7], [8], [9]–. Actually, it has been recently shown by SÖylernez [10] that it is possible to assign only the dominant poles of a system with the help of a multi-loop PI controller and guarantee that the rest of the closed-loop system poles remain in a predescribed left half-plane. The method described in [10] allows the designer to find all such compensators. Therefore, it is possible to satisfy further design criteria with the help of such a method.

This study considers, the application of the dominant pore assignment method to a permanent magnet synchronous motor (PMSM) driven single-link robot arm. PMS motors are attractive for high performance applications like direct-drive systems because of their high torque over a wide speed range, high acceleration/deceleration and high torque/inertia ratio, and therefore get the attention of researchers [11], [12], [13]. The control law is designed to achieve robustness and a good performance in spite of parameter uncertainties, and load variations.
The main contribution of this paper is the derivation and implementation of a robust multi-loop PID controller for the PMSM driven single-link robot arm. It has been shown, in particular, that it is possible to assign dominant poles of the system arbitrarily and then choose the free parameters in the design to guarantee stability, to restrict the control signal to reduce the sensitivity with respect to disturbances and to increase robustness for load uncertainties. The experiment results are highly satisfactory to validate the proposed approach.

This paper is organized as follows: The general method of assigning dominant poles with multi-loop PI controllers is explained in the next section. Section III introduces the mathematical model of the single-link robot arm. The application of the design method to this model is explained in Section IV. This is followed by the experimental results presented in Section V. Finally, Section VI provides conclusive remarks and suggestions for the future work.

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II. ROBOTIC ARM MODEL

This example uses the six degree-of-freedom robotic arm shown below. This arm consists of six joints labeled from base to tip: "Turntable", "Bicep", "Forearm", "Wrist", "Hand", and "Gripper". Each joint is actuated by a DC motor except for the Bicep joint which uses two DC motors in tandem. Figure 1 represents the robotic arm with 6 degree of freedom in different views.

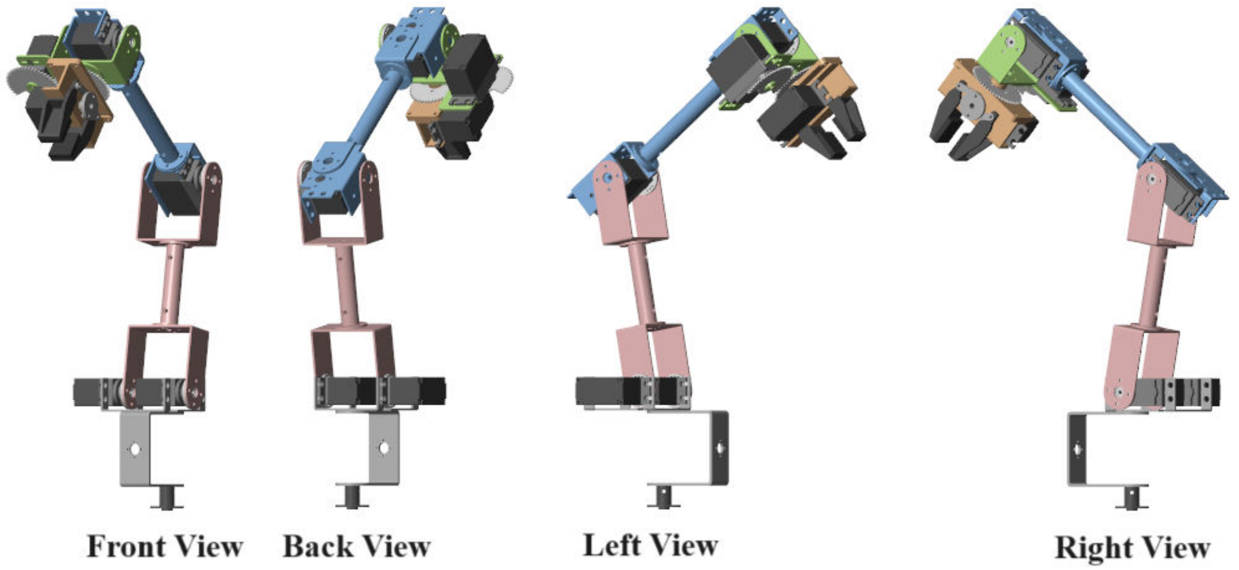

Figure 1: The robotic arm with 6 degree of freedom from different viewing angles

In Simulink the robotic arm is implemented using electrical servo motors and various control equations. Figure 2 represents the Simulink implementation of the robotic arm.Here, the Cartesian space coordinate system is established through forward and inverse kinematics to solve the position of the end effector such as the rotation matrix movement angle, etc. And the joint is controlled by adjusting the torque of the motor.The biggest concern in robotic arm is the accuracy of therobot in completing the task of picking and placing an object.The accuracy of the robotic arm depends on the designedcontroller of the robot. Here in this work, we have proposed a 2-DOF based auto-tuned PID controller for robotic arm motion control.

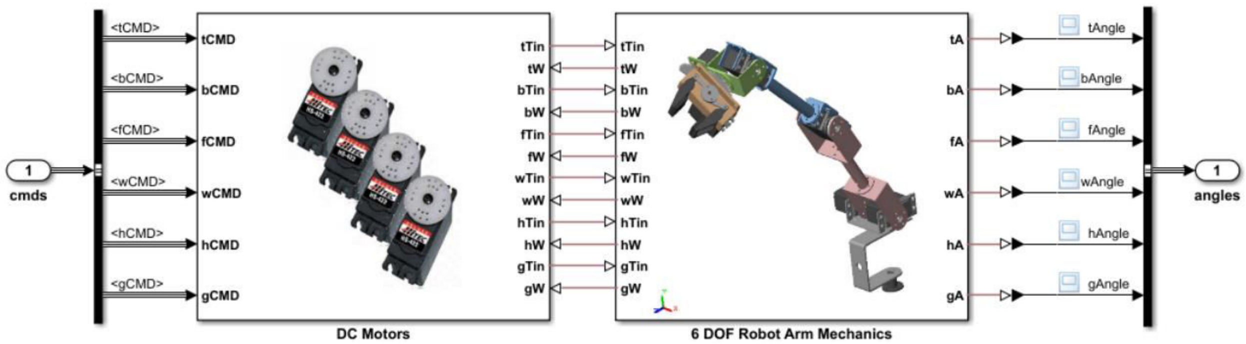

Figure 2: Block diagram of the 6 degree robotic ARM in Simulink

III. PID CONTROLLER DESIGN

The "Controller" subsystem consists of five digital PID controllers (one per joint). Each PID controller is implemented using the "2-DOF PID Controller" block from the Simulink library. The control sample time is Ts=0.1 (10 Hz). Typically, such multi-loop controllers are tuned sequentially by tuning one PID loop at a time and cycling through the loops until the overall behaviour is satisfactory. This process can be time consuming and is not guaranteed to converge to the best overall tuning. Alternatively, we can use systune or looptune MATLAB functions to jointly tune all five PI loops subject to system-level requirements such as response time and minimum cross-coupling.

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In this paper, the arm must move to a particular configuration in about 1 second with smooth angular motion at each joint. The arm starts in a fully extended vertical position with all joint angles at zero except for the Bicep angle at ninety degrees. The end configuration is specified by the angular positions: Turntable = 60 deg, Bicep = 80 deg, Forearm = 60 deg, Wrist = 90 deg, Hand = 90 deg, and Gripper = 60 deg. Figure 4 represent the block diagram of the implementation of the proposed PID controller sub system.

A. 2-DOF PID Controllers

Two-degree-of-freedom (2-DOF) PID controllers include setpoint weighting on the proportional and derivative terms. A 2-DOF PID controller is capable of fast disturbance rejection without significant increase of overshoot in setpoint tracking. 2-DOF PID controllers are also useful to mitigate the influence of changes in the reference signal on the control signal.

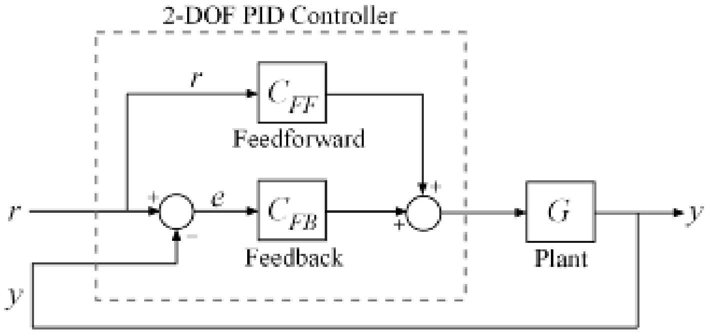

Figure 3: 2-DOF PID controller system block diagram

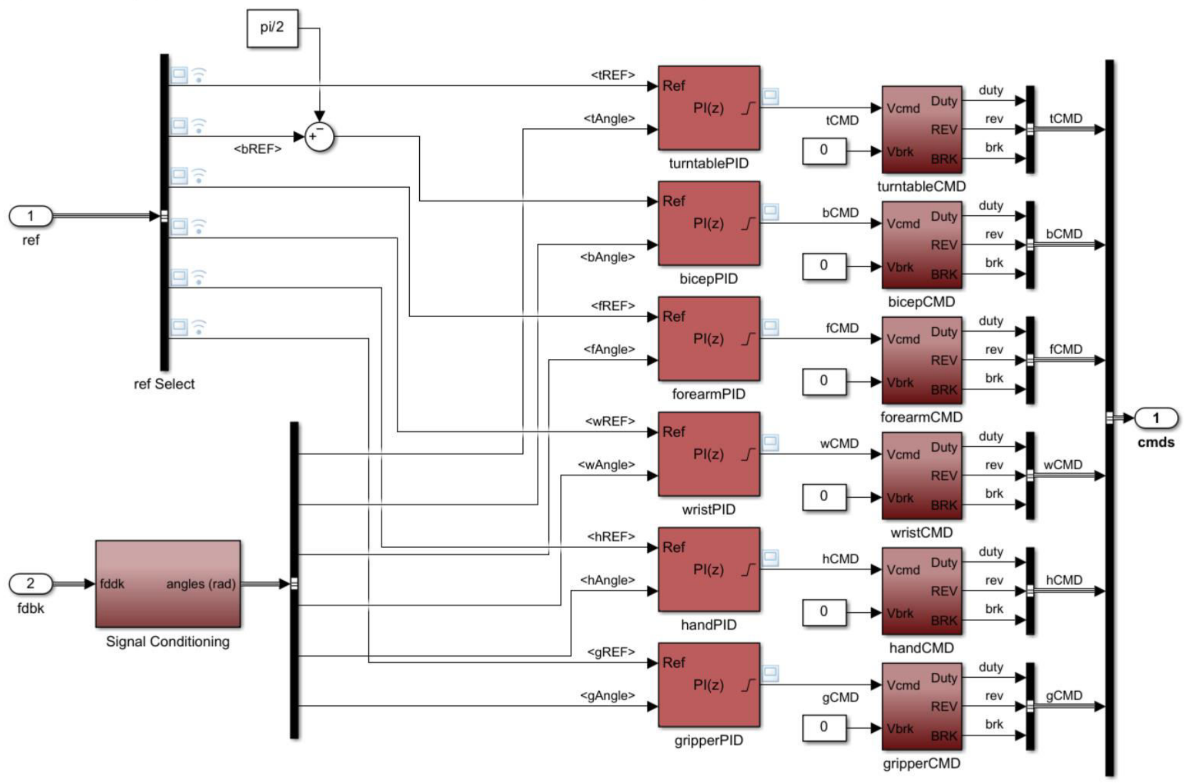

Figure 4: Block diagram of the proposed PID controller in Simulink

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V. RESULT AND DISCUSSION

After successful implementation, the proposed auto-tuned PID controller is simulated in Matlab Simulink for performance measurement. By default, looptune only tunes the feedback loop and does not "see" the feedforward component. This can be confirmed by verifying that the parameters of the PI controllers remain set to their initial value (type showTunable(ST1) to see the tuned values).

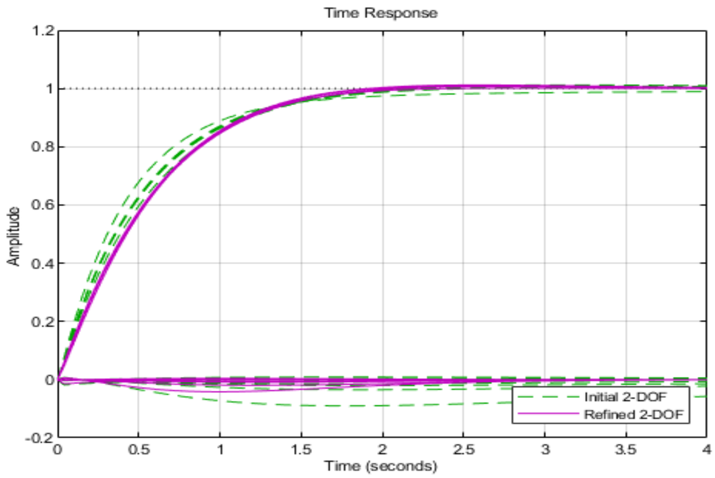

Figure 5: Time Response after implementing 2-DOF auto-tuning

To take advantage of the feedforward action and reduce overshoot, replace the bandwidth target by an explicit step tracking requirement from reference angles to joint angles. The 2-DOF tuning eliminates overshoot and improves the Bicep response. Figure 5 represents the 2-DOF response initially in green dashed line and Refined 2-DOF in pink solid line. Figure 6 represents the response of the proposed auto-tuned 2-DOF based PID robotic controller. For this graph, it can be inferred that after implementing 2-DOF based autotuning, the proposed PID works better.

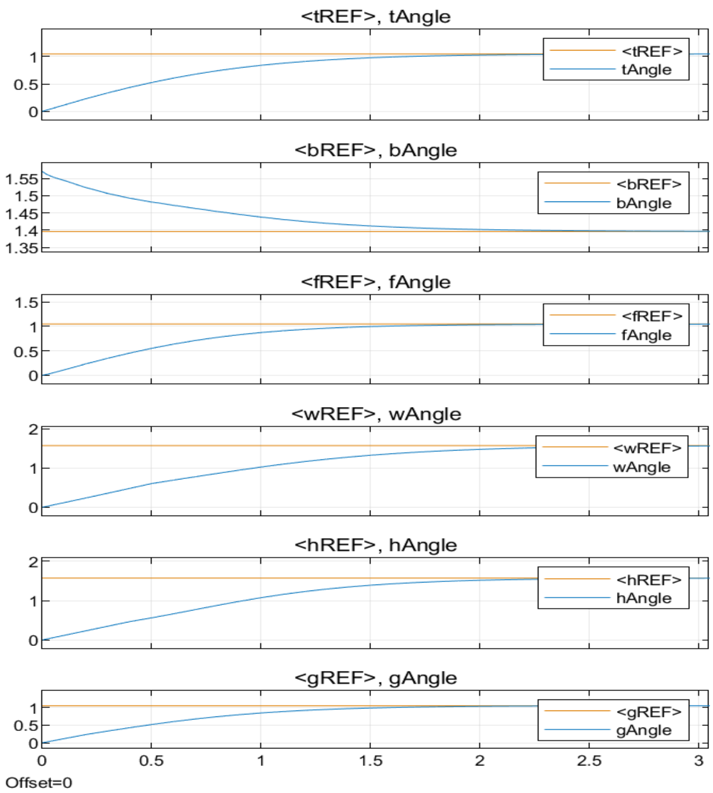

Figure 5: Result of the Autotuned PID Controller

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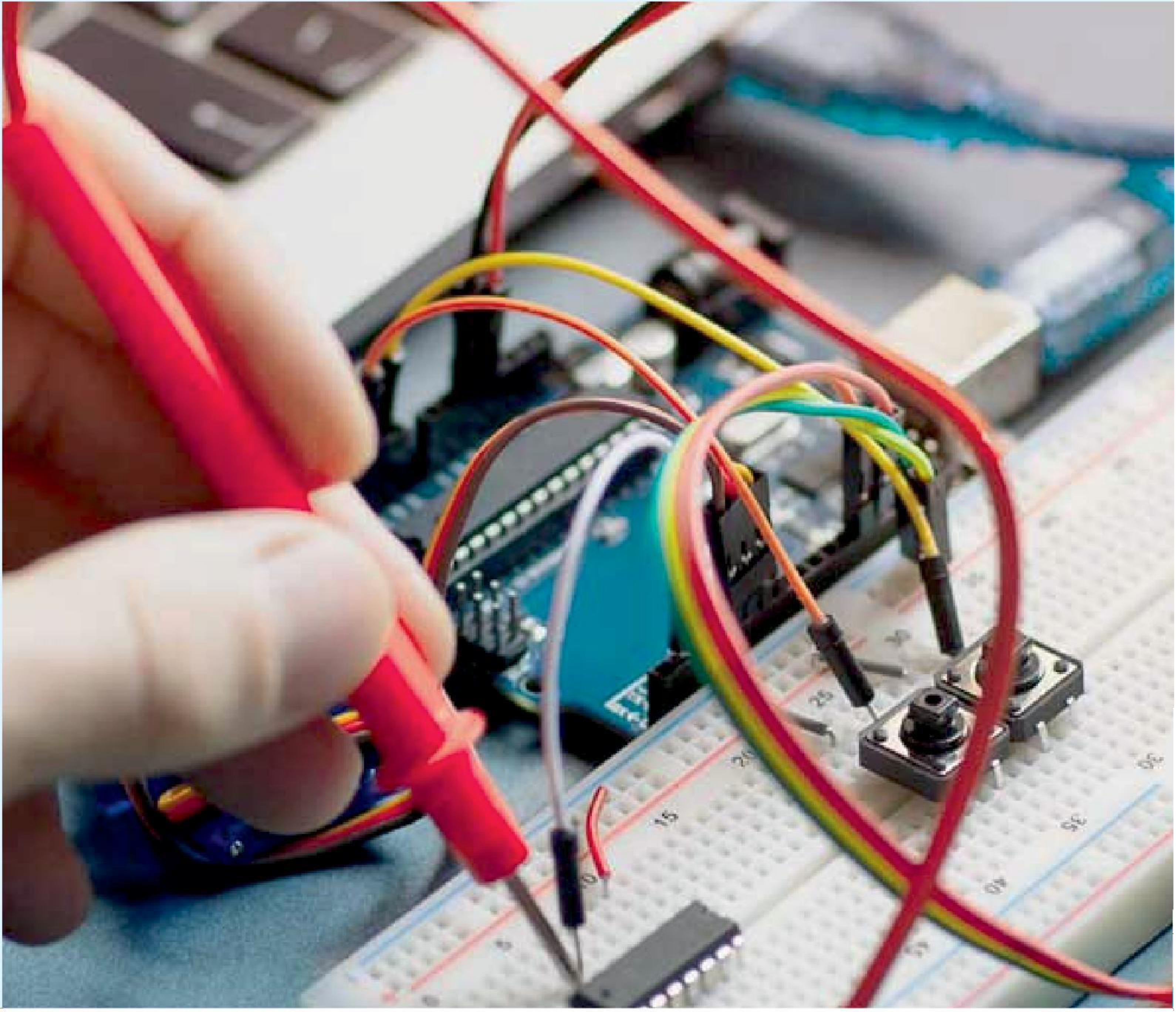
VI.CONCLUSION

In this study, the proposed controller of the robotic arm model shows that it can assist in completing pick-and-place task. However, the study can be improved by using more precise and sensitive sensors and motors. This study could also use other methods of tuning the PID controller and compare the outputs of the system between them in order to find the most suitable tuning method for this project. The simulation of the position of the robotic arm represents the position of the real robotic arm. Based on the simulation, the angular displacement of the robot's joints calculated using the kinematics analysis are programmed in the MATLAB GUI coding where the MATLAB GUI displays the simulation of the robotic arm movements. By conducting two simulations of the kinematics analysis, it can be concluded that the calculation for the robotic arm is only required for 2-DOF to reach the desired point.

REFERENCES

[1] K. J. Åström and T. Hägglund, "PID control" in The Control Handbook, Florida:CRC Press, pp. 198-209, 1996.
[2] K. J. Åström and T. Hägglund, "Automatic Tuning of PID Controllers", Instrument Society of America, 1988.
[3] K. A. Åström and T. Hägglund, "The future of PID control", Chem. Eng. Prog., vol. 9, pp. 1163-1175, 2001.
[4] M.-T. Ho, A. Datta and S. P. Bhattacharyya, "A linear programming characterization of all stabilizing PID controllers", Proc. Amer. Contr. Conf., pp. 3922-3928, 6 1997.
[5] M. T. Söylemez, N. Munro and H. Baki, "Fast calculation of stabilizing PID compensatom", Automatica, vol. 39, pp. 121-126, 2003.
[6] H. Baki, H. Wang, M. T. Söylemez and N. Munro, "Implementing machine-directional basis weight control for a pilot paper machine", Control Eng. Prac., vol. 9, no. 6, pp. 621-630, 6 2001.
[7] W. M. Wenham and A. S. Morse, "Feedback invariants of linear multivariable systems", Automatica, vol. 8, pp. 93-100, 1972.
[8] M. T. Söylemez, Pole Assignment for Uncertain Systems sec UMIST Control System Centre Series, London:RSP, 1999.
[9] M. T. Söylemez and N. Munro, "A new technique for partial pole placement using constant output-feedback", Conf. Decision Cantr, pp. 1722-1727, 12 1998.
[10] M. T. Söylemez, "Dominant pole placement using multi-loop pi controllers", to be Submitted to European Journal of Control, pp. 3, 2003.
[11] S. Bolognani, R. Oboe and M. Zigliotto, "Sensorless full-digital PMSM drive with EKF estimation of speed and rotor position", Trans. On Ind. Electron., vol. 46, no. 1, pp. 184-191, 1999.
[12] L. Salvatore and S. Stasi, "Adaptive position control of a PMSM drive", Proc. Int. Conf. On Indust. Electron. Contr. Instrumenta. And Automat., pp. 2079-2085, 1994.
[13] O. S. Bogosyan and M. Gokasan, "Adaptive torque ripple minimization of pennanent magnet synchronous motors for direct drive applications", 3D th Ind. Appl. Annual Meeting, pp. 231-237, 1995.



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