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Position and Speed Control of 2 DOF Industrial Robotic Arm using Robust Controllers

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Abstract

In this paper, a 2 DOF industrial robotic arm is designed and simulated for elbow and wrist angle and velocity performance improvement using robust control method. Mixed H₂/H_∞ synthesis with regional pole placement and H₂ optimal controllers are used to improve the system output. The open loop response of the robot arm shows that the elbow and wrist angles and velocities need some improvement. Comparison of the proposed controllers for an impulse and step input signals have been done and a promising results have been obtained.

Keywords: Industrial robotic arm, Mixed H₂/H_∞ synthesis with regional pole placement controller, H₂ optimal controller

1. Introduction

A robotic arm is a makes of mechanical arm, usually programmable, with similar functions to a human arm; the system may be the sum total of the mechanism or may be segment of a more complex robot. The links of such a system are connected by joints allowing either as articulated robot or linear displacement robot. The links of the robot can be considered to form a kinematic chain. The overall system of the kinematic chain of the manipulator is called the end effector and it is analogous to the human arm. However, the assembly "robotic hand" as a synonym of the robotic arm is often proscribed.

2. Mathematical Modeling of the Robot Arm

The 2 DOF industrial robot arm can be modeled as shown in Figure 1 below.

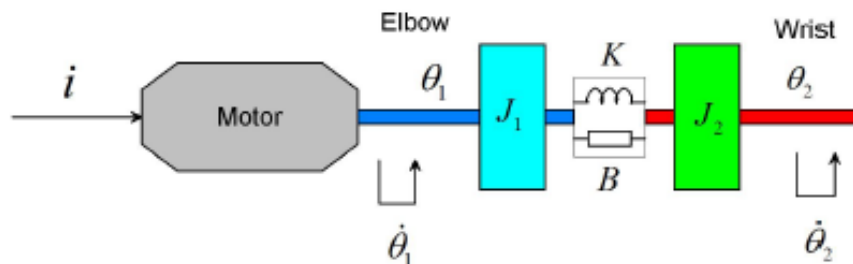


Figure 1 Industrial robot arm design

The equation of motion at the elbow is

$$J_1 \ddot{\theta}_1 + B\dot{\theta}_1 + K\theta_1 - B\dot{\theta}_2 - K\theta_2 = T = K_T i \quad (1)$$

The equation of motion at the wrist is

$$J_2 \ddot{\theta}_2 + B\dot{\theta}_2 + K\theta_2 - B\dot{\theta}_1 - K\theta_1 = 0 \quad (2)$$

Let

$$x_1 = \theta_1, x_2 = \dot{\theta}_1, x_3 = \theta_2, x_4 = \dot{\theta}_2 \text{ and } i = u$$

So the state space representation becomes

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{bmatrix} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ -\frac{K}{J_1} & -\frac{B}{J_1} & \frac{K}{J_1} & \frac{B}{J_1} \\ 0 & 0 & 0 & 1 \\ \frac{K}{J_2} & \frac{B}{J_2} & -\frac{K}{J_2} & -\frac{B}{J_2} \end{pmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{K_T}{J_1} \\ 0 \\ 0 \end{bmatrix} u$$

$$y = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$$

The system parameters are shown in Table 1 below.

Table 1 System parameters

No	Parameters	Symbol	Value
	Moment of inertia of the elbow	J_1	$3 \text{ Kg m}^2 / \text{s}^2$
	Moment of inertia of the wrist	J_2	$2 \text{ Kg m}^2 / \text{s}^2$
	Damping coefficient of the system	B	$8 \text{ N.s} / \text{m}$
	Spring Stiffness of the system	K	$6 \text{ N} / \text{m}$
	Torque Constant	K_T	$4 \text{ Nm} / \text{A}$

The state space numerically becomes:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{bmatrix} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ -2 & -2.67 & 2 & 2.67 \\ 0 & 0 & 0 & 1 \\ 3 & 4 & -3 & -4 \end{pmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 0 \\ 1.3 \\ 0 \\ 0 \end{bmatrix} u$$

$$y = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$$

3. Proposed Controller Design

3.1 Mixed H₂/H_∞ with Regional Pole Placement Controller design

The mixed H₂/H_∞ control problem is to minimize the H₂ rule of overall state feedback output gains k and also satisfies the H_∞ norm gain. Mixed H₂/H_∞ synthesis with regional pole placement is one of the main example of multi-objective design by using the LMI approach. The mixed H₂/H_∞ synthesis with regional pole placement is sketched in Figure 2. The output of the system z is associated with the H_∞ achievement while the output z_2 is associated with the H₂ performance.

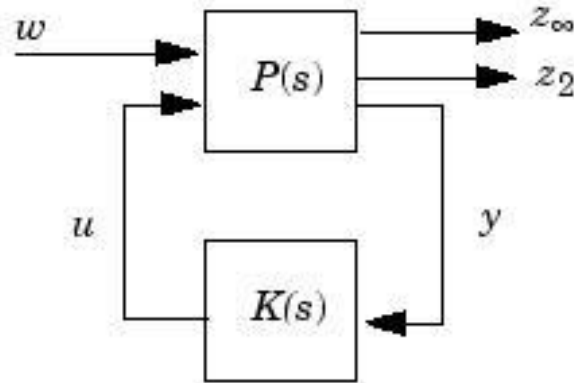


Figure 2 Mixed H₂/H_∞ configuration

The industrial robot arm with mixed H₂/H_∞ controller block diagram is shown in Figure 3 below.

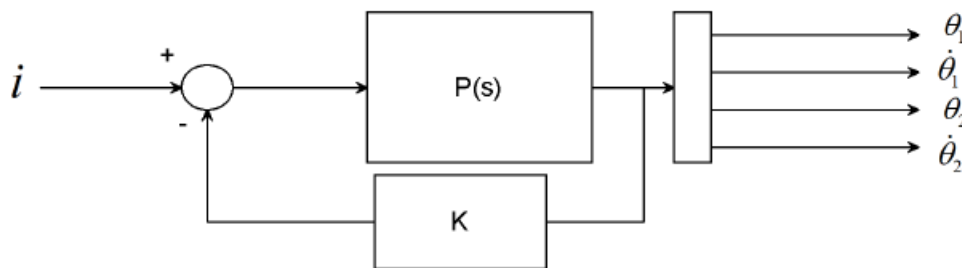


Figure 3 Industrial robot arm with mixed H₂/H_∞ controller block diagram

3.2 H₂ Optimal Controller Design

There are many track in which feedback design problems can be cast as H₂ optimization problems. It is very useful therefore to have a ancestor funeral planning into which any particular problem may be manipulated. Such a general formulation is afforded by the general arrangement shown in Figure 4.

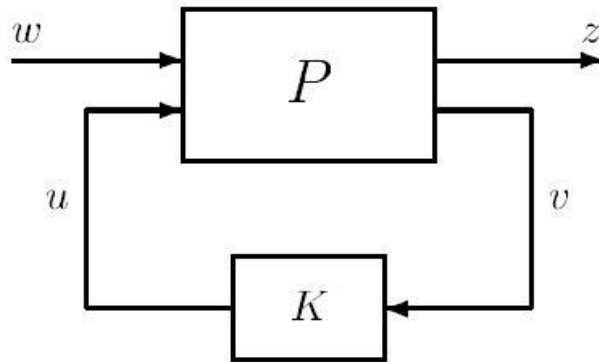


Figure 4 General control configuration

The signals are: u the sovereignty variables, v the measured variables, w the exogenous signals such as disturbances w and domination r , and z the so-called "error" signals which are to be minimized in some way to meet the dominion objectives. The industrial robot arm with H₂ optimal controller block diagram is shown in Figure 5.

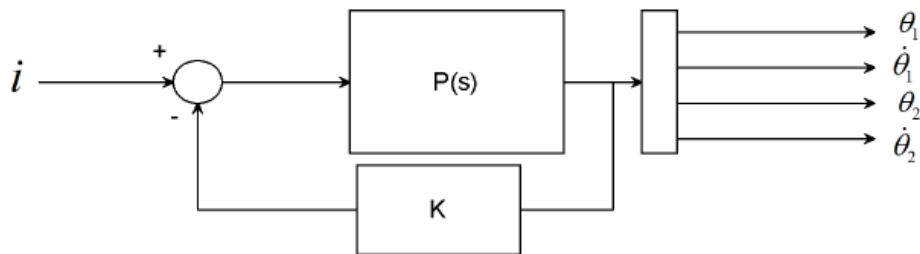


Figure 5 Industrial robot arm with H₂ optimal controller block diagram

4. Result and Discussion

4.1 Open Loop Response

The open loop impulse and step response of the industrial robot arm for elbow angle and angular velocity and wrist angle and angular velocity with a current input of 10A is shown in Figure 6 and Figure 7 respectively.

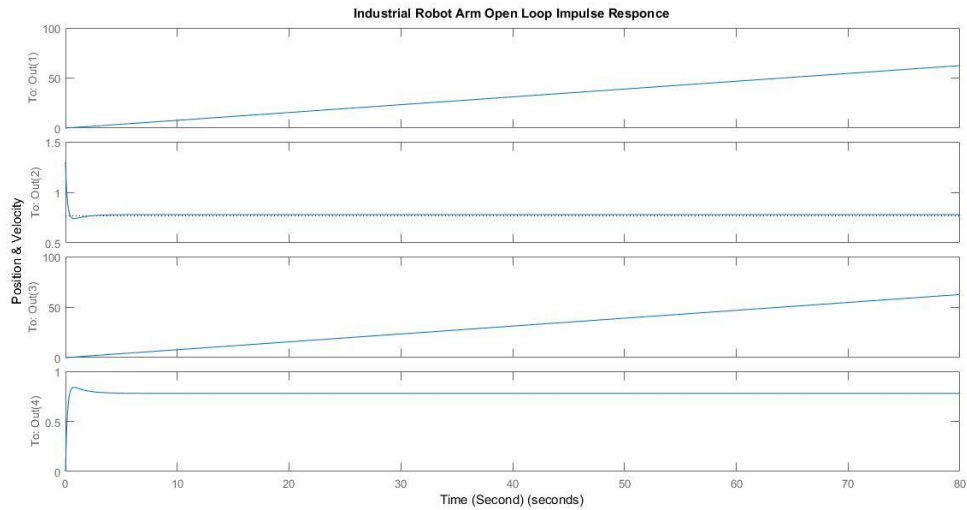


Figure 6 Open loop impulse response

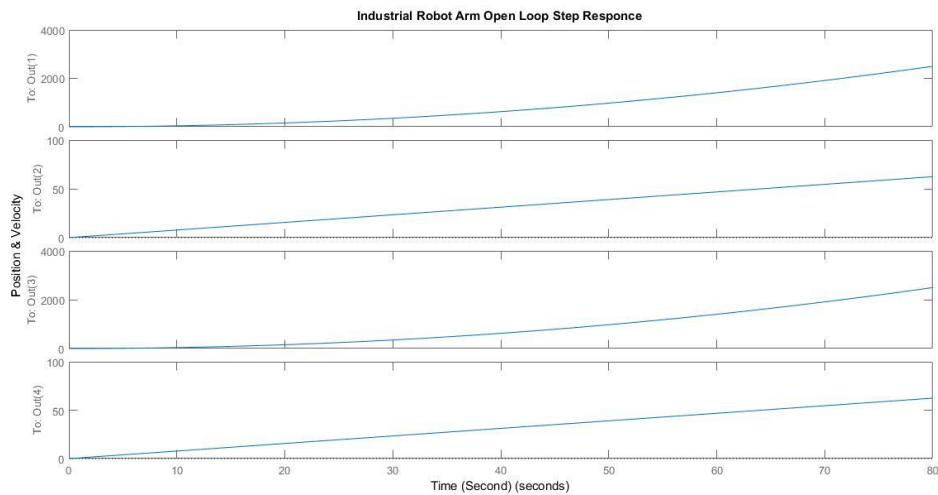


Figure 7 Open loop step response

The open loop impulse response simulation shows that the elbow and wrist angle increases linearly and not settled but the elbow and wrist angular velocity have been settled to some values.

The open loop step response simulation shows that the elbow and wrist angle and angular velocity increases linearly and not settled.

4.2 Comparison of the Industrial Robot Arm with Mixed H_2/H_∞ and H_2 Optimal Controllers for Impulse and Step Input Signals

The Comparison of the industrial robot arm with mixed H_2/H_∞ and H_2 optimal controllers for an impulse and step input signals for elbow angle and angular velocity and wrist angle and angular velocity with a current input of 10A is shown in Figure 8 and Figure 9 respectively.

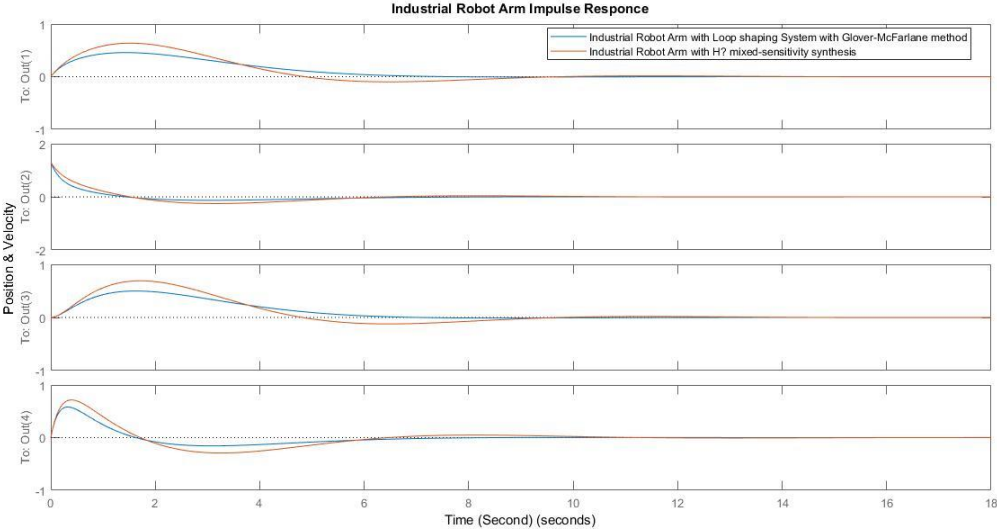


Figure 8 Impulse response comparison

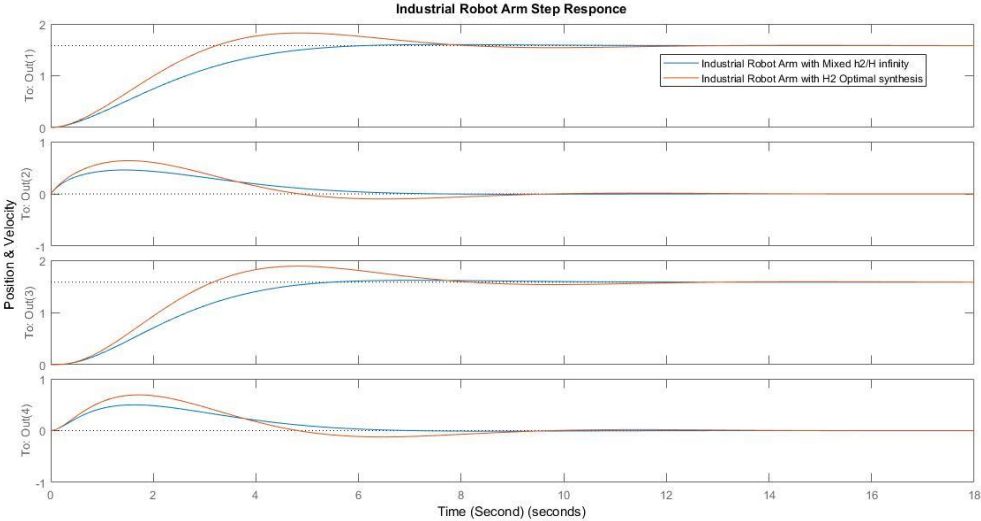


Figure 9 Step response comparison

The impulse response comparison shows that the elbow and wrist angles and velocities are affected by the impulse input current but the industrial robot arm with mixed H_2/H_∞ shows a good performance in minimizing the settling time.

The step response comparison shows that the elbow and wrist angles are controlled with a better settling time and the elbow and wrist angular velocities shows a good settling times but the industrial robot arm with mixed H_2/H_∞ shows a good performance in minimizing the settling time and overshoot.

5. Conclusion

In this paper, a 2 DOF industrial robot arm is modeled and designed for performance improvement using mixed H_2/H_∞ synthesis with regional pole placement and H_2 optimal controllers with the aid of Matlab/Script Toolbox. The open loop response of the robot arm shows that both the elbow and wrist angles and velocities need to be improved. Comparison of the system with the proposed controllers have been done for an impulse and step input current signals. Finally, the comparison simulation results proved that the proposed mixed H_2/H_∞ synthesis with regional pole placement controller improves the robot arm angle and velocity better than the proposed H_2 optimal controller.

Reference

- [1].Hao Jiang et al. “Design Control and Application of a Soft Robotic Arm” International Journal of Robotics Research, Vol. 12, Issue 1, 2019.
- [2].B. Kayani et al. “Robotic Arm Assisted Total Knee Arthroplasty is Associated with Improved Early Functional Recovery and Reduced Time to Hospital Discharge Compared with Conventional Jig Based Total Knee Arthroplasty” The Bone & Joint Journal, Vol. 100-B No. 7, 2018.
- [3].Mesut H. et al. “Dynamic Model and Control of 2-DOF Robotic Arm” European Journal of Technique, Vol. 8, Issue 2, pp. 141-150, 2018.
- [4].Alit Swamardika et al. “Design of Mobile Robot with Robotic Arm Utilising Microcontroller and Wireless Communication” International Journal of Engineering and Technology, Vol. 9, Issue 2, pp. 838-846, 2017.
- [5].Leijie Jiang et al. “Design and Nonlinear Control of a 2 DOF Flexible Parallel Humanoid Arm Joint Robot” Journal of Shock and Vibration, Vol. 2017, Article ID 2762169, 2017.
- [6].Chaudhary H. et al. “Adaptive Neuro Fuzzy Based Hybrid Force/Position Control for an Industrial Robot Manipulator” Journal of Intelligent Manufacturing, Vol. 27, Issue 6, pp. 1299-1308, 2016.
- [7].Abut T. “Modeling and Optimal Control of a DC Motor” Int. J. Eng. Trends Technol, Vol. 32, Issue 3, pp.146-150, 2016.
- [8].He W. et al. “Adaptive Neural Impedance Control of a Robotic Manipulator with Input Saturation” IEEE Trans. Syst. Man Cybern. Syst, Vol. 46, Issue 3, pp.334-344, 2016.