Studies on the influences of design parameters on the control characteristics of robot arm

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ABSTRACT

Robot manipulators have the inherent characteristics of being highly non-linear and strongly coupled. Due to this complexity, the design of a general robot arm is an expensive and time-consuming task. Two-link manipulators are two-degree-of-freedom robots. Proportional-Integral-Derivative (PID) control is the most common control algorithm used in industrial control systems.

In the present work, a feed-forward controller structure consisting of feedback and feed-forward controller was employed in order to eliminate positional inaccuracy due to reproducible disturbances and model uncertainty.

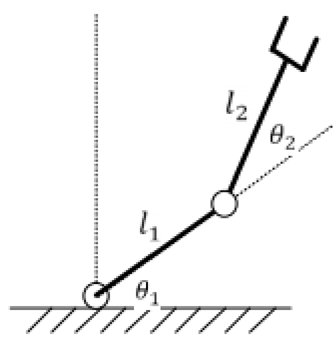

Figure 1: A two-dof robot arm

According to Lagrange's equation, the arm dynamics are given by the two-coupled non-linear differential equations:

$$\tau_1 = [(m_1+m_2)l_1^2 + m_2 l_2^2 + 2m_2 l_1 l_2 cos\theta_2]\ddot{\theta}_1 + [m_2 l_2^2 + m_2 l_1 l_2 cos\theta_2]\ddot{\theta}_2$$
$$-2m_2 l_1 l_2 \dot{\theta}_1 \dot{\theta}_2 sin\theta_2 - m_2 l_1 l_2 \dot{\theta}_2^2 sin\theta_2 + (m_1+m_2) g l_1 cos\theta_1 + m_2 g l_2 \cos(\theta_1+\theta_2)$$

$$\tau_2 = [m_2 l_2^2 + m_2 l_1 l_2 cos\theta_2]\ddot{\theta}_1 + m_2 l_2^2 \ddot{\theta}_2 \ + m_2 l_1 l_2 \dot{\theta}_1^2 sin\theta_2 \ + m_2 g l_2 cos(\theta_1 + \theta_2)$$

where θ_1, θ_2 angels of link 1, 2; m_1, m_2: masses of link 1, 2; a_1, a_2: lengths of link 1, 2.

The arm dynamics in vector form yields:

$$\begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} \begin{bmatrix} \ddot{\theta}_1 \\ \ddot{\theta}_2 \end{bmatrix} + \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix} + \begin{bmatrix} G_1 \\ G_2 \end{bmatrix} = \begin{bmatrix} \tau_1 \\ \tau_2 \end{bmatrix}$$

$$M_{11} = (m_1 + m_2) l_1^2 + m_2 l_2^2 + 2 m_2 l_1 l_2 cos\theta_2$$

$$M_{12} = m_2 l_2^2 + m_2 l_1 l_2 cos\theta_2$$

$$M_{21} = m_2 l_2^2 + m_2 l_1 l_2 cos\theta_2$$

$$M_{22} = m_2 l_2^2$$

$$C_{11} = -2 m_2 l_1 l_2 \dot{\theta}_2 sin\theta_2$$

$$C_{12} = -m_2 l_1 l_2 \dot{\theta}_2 sin\theta_2$$

$$C_{21} = m_2 l_1 l_2 \dot{\theta}_1 sin\theta_2$$

$$C_{22} = 0$$

$$G_1 = (m_1 + m_2) g l_1 cos\theta_1 + m_2 g l_2 cos(\theta_1 + \theta_2)$$

$$G_2 = m_2 g l_2 cos(\theta_1 + \theta_2)$$

The feed-forward controller compensates the reproducible disturbances that depend on the state of the process.

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