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.

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

\[
\tau_1 = [(m_1 + m_2)l_1^2 + m_2l_2^2 + 2m_2l_1l_2\cos \theta_2] \ddot{\theta}_1 + [m_2l_2^2 + m_2l_1l_2\cos \theta_2] \ddot{\theta}_2
\]
\[
-2m_2l_1l_2\dot{\theta}_1\dot{\theta}_2\sin \theta_1 - m_2l_1l_2\dot{\theta}_2^2\sin \theta_2 + (m_1 + m_2)gl_1\cos \theta_1 + m_2gl_2\cos(\theta_1 + \theta_2)
\]
\[ \tau_2 = [m_2l_2^2 + m_2l_1l_2\cos\theta_2]\ddot{\theta}_1 + m_2l_2^2\ddot{\theta}_2 + m_2l_1l_2\dot{\theta}_1^2\sin\theta_2 + m_2gl_2\cos(\theta_1 + \theta_2) \]

where \( \theta_1, \theta_2 \) are the angles of link 1, 2; \( m_1, m_2 \) are the masses of link 1, 2; \( a_1, a_2 \) are the lengths of link 1, 2.

The arm dynamics in vector form yields:

\[
\begin{bmatrix}
M_{11} & M_{12} \\
M_{21} & M_{22}
\end{bmatrix}
\begin{bmatrix}
\dot{\theta}_1 \\
\dot{\theta}_2
\end{bmatrix} +
\begin{bmatrix}
C_{11} & C_{12} \\
C_{21} & C_{22}
\end{bmatrix}
\begin{bmatrix}
\theta_1 \\
\theta_2
\end{bmatrix} +
\begin{bmatrix}
G_1 \\
G_2
\end{bmatrix} = \begin{bmatrix}
\tau_1 \\
\tau_2
\end{bmatrix}
\]

\[ M_{11} = (m_1 + m_2)l_1^2 + m_2l_2^2 + 2m_2l_1l_2\cos\theta_2 \]

\[ M_{12} = m_2l_2^2 + m_2l_1l_2\cos\theta_2 \]

\[ M_{21} = m_2l_2^2 + m_2l_1l_2\cos\theta_2 \]

\[ M_{22} = m_2l_2^2 \]

\[ C_{11} = -2m_2l_1l_2\dot{\theta}_2\sin\theta_2 \]

\[ C_{12} = -m_2l_1l_2\dot{\theta}_2\sin\theta_2 \]

\[ C_{21} = m_2l_1l_2\dot{\theta}_1\sin\theta_2 \]

\[ C_{22} = 0 \]

\[ G_1 = (m_1 + m_2)gl_1\cos\theta_1 + m_2gl_2\cos(\theta_1 + \theta_2) \]

\[ G_2 = m_2gl_2\cos(\theta_1 + \theta_2) \]

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

**References**


