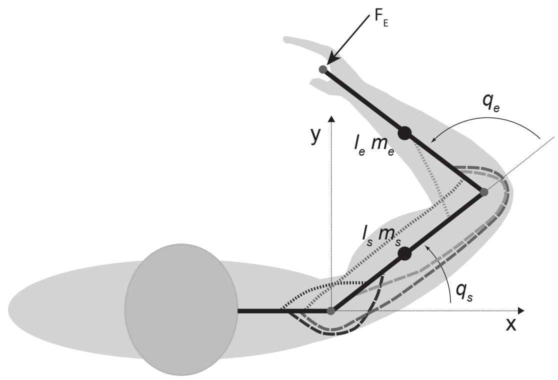
DYNAMICS OF 2-JOINT MODEL



$$\boldsymbol{\tau}_B = \mathbf{H}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{C}(\mathbf{q},\dot{\mathbf{q}})\dot{\mathbf{q}}\,, \quad \mathbf{H}(\mathbf{q}) = \begin{bmatrix} H_{ss} & H_{se} \\ H_{es} & H_{ee} \end{bmatrix},$$

$$H_{ss} = I_s + I_e + M_s\, l_{ms}^2 + M_e\,(l_s^2 + l_{me}^2 + 2\, l_s\, l_{me}\, c_e),$$
$$H_{se} = I_e + M_e\,(l_{me}^2 + l_s\, l_{me}\, c_e) = H_{es},$$
$$H_{ee} = I_e + M_e\, l_{me}^2\,,\ \ c_e \equiv \cos(q_e)\,,\ \ s_e \equiv \sin(q_e),$$

$$\mathbf{C}(\mathbf{q},\dot{\mathbf{q}})\dot{\mathbf{q}} = \begin{bmatrix} -M_e\, l_s\, l_{me}\, \dot{q}_e\,(2\,\dot{q}_s + \dot{q}_e)\, s_e \\ M_e\, l_s\, l_{me}\, \dot{q}_s^2 s_e \end{bmatrix}$$

m_s, m_e : masses of the upper and lower arms

l_s, l_e : corresponding segment lengths

l_{ms}, l_{me} : distances to the centers of mass

I_s, I_e : moments of inertia

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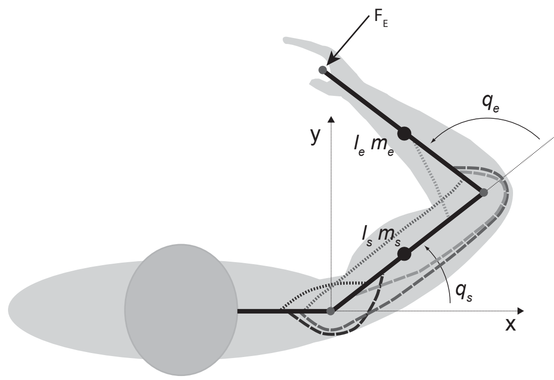

$$\boldsymbol{\tau}_B = \mathbf{H}(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{C}(\mathbf{q},\dot{\mathbf{q}})\dot{\mathbf{q}} = \boldsymbol{\Psi}(\mathbf{q},\dot{\mathbf{q}},\ddot{\mathbf{q}})\,\mathbf{p}$$

$$p_1 \equiv I_e + m_e\, l_{me}^2 \quad p_2 \equiv m_e\, l_s\, l_{me}$$
$$p_3 \equiv I_s + m_s\, l_{ms}^2 + m_e\, l_s^2$$

$$\Psi_{12} = c_e(2\ddot{q}_s + \ddot{q}_e) - s_e\dot{q}_e\,(2\dot{q}_s + \dot{q}_e)\ , \qquad \Psi_{13} = \ddot{q}_s$$
$$\Psi_{11} = \Psi_{21} = \ddot{q}_s + \ddot{q}_e\,,\ \Psi_{22} = c_e\ddot{q}_s + s_e\dot{q}_s^2\,,\ \Psi_{23} = 0$$

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