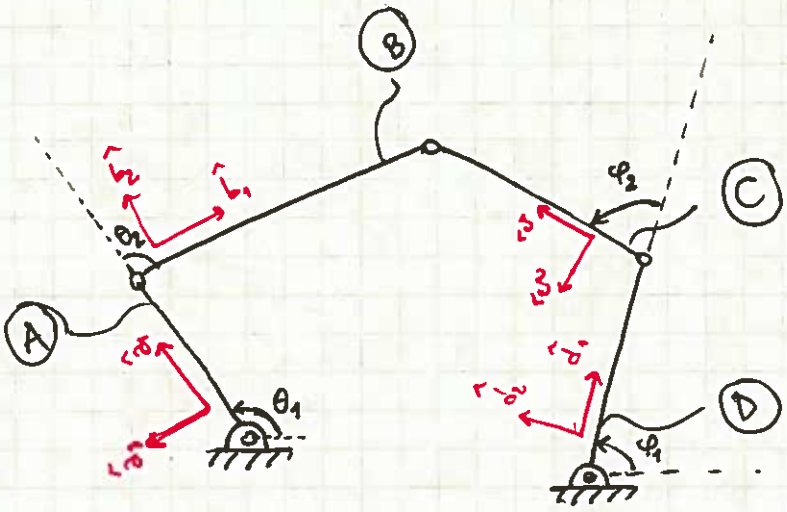
PANTOGRAPH



Position level

$$l_1 \hat{a}_1 + l_2 \hat{b}_1 - l_3 \hat{c}_1 - l_4 \hat{d}_1 - l_{0x} \hat{e}_1 + l_{0y} \hat{e}_2 = 0$$

$$l_1 \begin{pmatrix} c_{\theta_1} \\ s_{\theta_1} \end{pmatrix} + l_2 \begin{pmatrix} c_{\theta_{12}} \\ s_{\theta_{12}} \end{pmatrix} - l_3 \begin{pmatrix} c_{\varphi_{12}} \\ s_{\varphi_{12}} \end{pmatrix} - l_4 \begin{pmatrix} c_{\varphi_1} \\ s_{\varphi_1} \end{pmatrix} + \begin{pmatrix} -l_{0x} \\ l_{0y} \end{pmatrix} = 0 .$$

	Forward	Inverse
Known	θ_1, φ_1	θ_2, φ_2
Unknown	θ_2, φ_2	θ_1, φ_1

Velocity level

$$l_1 \dot{\theta}_1 \begin{pmatrix} -s_{\theta_1} \\ c_{\theta_1} \end{pmatrix} + l_2 (\dot{\theta}_1 + \dot{\theta}_2) \begin{pmatrix} -s_{\theta_{12}} \\ c_{\theta_{12}} \end{pmatrix} - l_3 (\dot{\varphi}_1 + \dot{\varphi}_2) \begin{pmatrix} -s_{\varphi_{12}} \\ c_{\varphi_{12}} \end{pmatrix} - l_4 \dot{\varphi}_1 \begin{pmatrix} -s_{\varphi_1} \\ c_{\varphi_1} \end{pmatrix} = 0$$

	Forward	Inverse
Known	$\dot{\theta}_1, \dot{\varphi}_1$	$\dot{\theta}_2, \dot{\varphi}_2$
Unknown	$\dot{\theta}_2, \dot{\varphi}_2$	$\dot{\theta}_1, \dot{\varphi}_1$

Acceleration level

$$l_1 \ddot{\theta}_1 \begin{pmatrix} -s_{\theta_1} \\ c_{\theta_1} \end{pmatrix} - l_1 \dot{\theta}_1^2 \begin{pmatrix} c_{\theta_1} \\ s_{\theta_1} \end{pmatrix} + l_2 (\ddot{\theta}_1 + \ddot{\theta}_2) \begin{pmatrix} -s_{\theta_{12}} \\ c_{\theta_{12}} \end{pmatrix} - l_2 (\dot{\theta}_1 + \dot{\theta}_2)^2 \begin{pmatrix} c_{\theta_{12}} \\ s_{\theta_{12}} \end{pmatrix}$$

$$- l_3 (\ddot{\varphi}_1 + \ddot{\varphi}_2) \begin{pmatrix} -s_{\varphi_{12}} \\ c_{\varphi_{12}} \end{pmatrix} + l_3 (\dot{\varphi}_1 + \dot{\varphi}_2)^2 \begin{pmatrix} c_{\varphi_{12}} \\ s_{\varphi_{12}} \end{pmatrix} - l_4 \ddot{\varphi}_1 \begin{pmatrix} -s_{\varphi_1} \\ c_{\varphi_1} \end{pmatrix} + l_4 \dot{\varphi}_1^2 \begin{pmatrix} c_{\varphi_1} \\ s_{\varphi_1} \end{pmatrix} = 0$$

	Forward	Inverse
Known	$\ddot{\theta}_1, \ddot{\varphi}_1$	$\ddot{\theta}_2, \ddot{\varphi}_2$
Unknown	$\ddot{\theta}_2, \ddot{\varphi}_2$	$\ddot{\theta}_1, \ddot{\varphi}_1$