

# ROB 530 Project Notes

rlybrdgs

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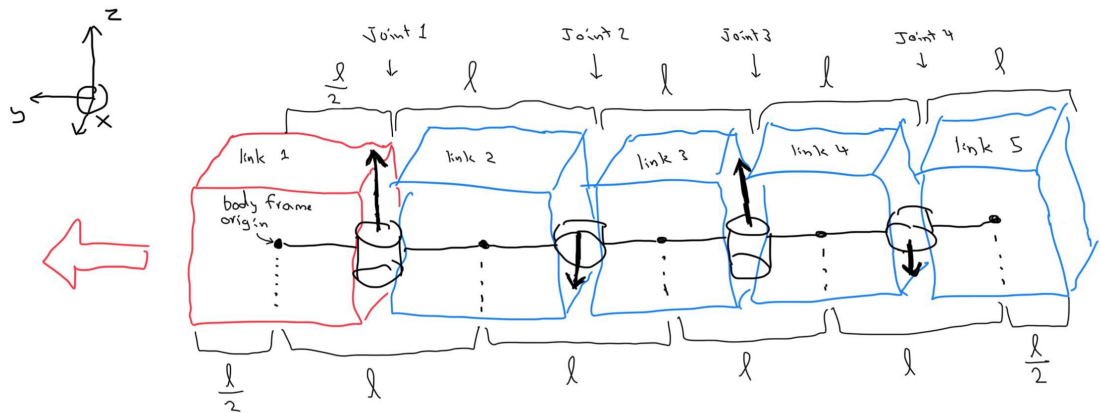


Figure 1: Example diagram of 4 joint snake robot.

## 1 Prediction Step

$$\mathbf{x}_k = \begin{bmatrix} a_k \\ q_k \\ \omega_k \\ \theta_k \\ \dot{\theta}_k \end{bmatrix} \in \mathbb{R}^{10+2N}$$

$$\mathbf{x}_k = f(\mathbf{x}_{k-1}, \mathbf{u}_k) + \mathbf{w}_k$$

$$= \begin{bmatrix} e^{-\tau\Delta t} a_{k-1} \\ \exp\left(-\frac{1}{2}\Psi(\omega_{k-1})\Delta t\right) q_{k-1} \\ \omega_{k-1} \\ \theta_{k-1} + \dot{\theta}_{k-1}\Delta t \\ (1-\lambda)\dot{\theta}_{k-1} + \lambda\mathbf{u}_k \end{bmatrix}$$

$$q_k = \exp\left(-\frac{1}{2}\Psi(\omega_{k-1})\Delta t\right) q_{k-1}$$

$$= \left( I \cos\left(\frac{\|\omega_{k-1}\Delta t\|}{2}\right) - \frac{1}{2} \begin{bmatrix} 0 & -\omega^x\Delta t & \omega^y\Delta t & \omega^z\Delta t \\ -\omega^x\Delta t & 0 & -\omega^z\Delta t & -\omega^y\Delta t \\ -\omega^y\Delta t & \omega^z\Delta t & 0 & -\omega^x\Delta t \\ -\omega^z\Delta t & -\omega^y\Delta t & \omega^x\Delta t & 0 \end{bmatrix} \frac{\sin(\|\omega_{k-1}\Delta t\|)}{\|\omega_{k-1}\Delta t\|} \right) q_{k-1}$$

$$F_k = \frac{\partial f}{\partial \mathbf{x}_{k-1}} = \begin{bmatrix} e^{-\tau\Delta t} & 0 & 0 & 0 & 0 \\ 0 & \frac{\partial q_k}{\partial q_{k-1}} & \frac{\partial q_k}{\partial \omega_{k-1}} & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & \Delta t \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\frac{\partial q_k}{\partial q_{k-1}} =$$

$$\frac{\partial q_k}{\partial \omega_{k-1}} =$$

## 2 Forward Kinematics

$$g_{st}(\theta) = e^{\hat{\xi}_1\theta_1} e^{\hat{\xi}_2\theta_2} \dots e^{\hat{\xi}_N\theta_N} g_{st}(0)$$

$$g_{si}(\theta) = e^{\hat{\xi}_1\theta_1} e^{\hat{\xi}_2\theta_2} \dots e^{\hat{\xi}_{i-1}\theta_{i-1}} g_{si}(0)$$

$$\xi_i = \begin{bmatrix} -\omega_i \times q_i \\ \omega_i \end{bmatrix}$$

$$\begin{aligned}
\omega_i &= \begin{cases} \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}^\top & i \text{ is even} \\ \begin{bmatrix} 0 & 0 & 1 \end{bmatrix}^\top & i \text{ is odd} \end{cases} \\
q_i &= \begin{bmatrix} 0 \\ \frac{l}{2} + \sum_{j=1}^{i-1} l \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ l(i - \frac{1}{2}) \\ 0 \end{bmatrix} \\
\xi_i &= \begin{cases} \begin{bmatrix} 0 & 0 & -l(i - \frac{1}{2}) & 1 & 0 & 0 \end{bmatrix}^\top & i \text{ is even} \\ \begin{bmatrix} l(i - \frac{1}{2}) & 0 & 0 & 0 & 0 & 1 \end{bmatrix}^\top & i \text{ is odd} \end{cases} \\
g_{si}(0) &= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & l(i - 1) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}
\end{aligned}$$

### 3 Update Step

$$\begin{aligned}
\mathbf{z}_k &= \begin{bmatrix} \phi_k \\ \alpha_k \\ \gamma_k \end{bmatrix} \in \mathbb{R}^{7N} \\
\hat{\mathbf{z}}_k &= h(\mathbf{x}_k) \\
&= \begin{bmatrix} \theta_k \\ W_k^1 R_k g + \hat{a}_{\text{motion}}^1 \\ \vdots \\ W_k^N R_k g + \hat{a}_{\text{motion}}^N \\ \bar{\omega}^1 + (W_k^1)^\top \omega_k \\ \vdots \\ \bar{\omega}^N + (W_k^N)^\top \omega_k \end{bmatrix} \\
W_k^i &= C_k g_{si}(\theta_k)
\end{aligned}$$