



$$P_i = \begin{bmatrix} a_i \\ d \sin \alpha_i \\ d \cos \alpha_i \end{bmatrix} \Rightarrow \text{constant (local frame)}$$

FORWARD : $1 \leq i \leq n$ where n is the number of DOFs

$$W_i = (R_{i-1}^i)^T (W_{i-1} + \dot{\theta}_i z)$$

$$\dot{W}_i = (R_{i-1}^i)^T (\dot{W}_{i-1} + \ddot{\theta}_i z + W_{i-1} \times \dot{\theta}_i z)$$

$$\dot{V}_i = (R_{i-1}^i)^T \dot{V}_{i-1} + \dot{W}_i \times P_i + W_i \times (W_i \times P_i)$$

Backward $n \geq i \geq 1$

$$V_{ci} = V_i + \dot{W} \times r + W \times W \times r$$

$$F_i = m_i V_{ci}$$

$$N_i = I_i \dot{W}_i + W_i \times I_i W_i$$

$$n_i = R_i^{iH} \left\{ n_{i+1} + \left((R_i^{iH})^T P_i \right) \times f_{i+1} + (r_i + P_i) \times F_i \right\} + N_i$$

$$f_i = R_i^{iH} f_{i+1} + F_i$$

Finally :

$$Q_i = f_i (R_{iH}^i)^T z \quad \text{for translational joint}$$

$$Q_i = n_i (R_{iH}^i)^T z \quad \text{for rotational joint}$$