How the torque loop works.

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The robot's motors are controlled by using PWM signals applied to the motors. Assuming that each motors affects the position of only one link via rigid transmission mechanisms, the relationship between the link's torque τ and the motor's duty cycle PWM is assumed to be:

$$PWM = PWM_{\text{control}} + k_v \dot{q} + k_c \text{sign}(\dot{q}),$$

with k_{ff}, k_v, k_c three constants, and $\dot{q}$ the joint's velocity. Since discontinuities may be challenging in practice, it is best to smooth the sign function. For the sake of simplicity during the implementation process, we choose a pseudo sign function defined as follows:

$$PWM = PWM_{\text{control}} + k_v \dot{q} + k_c \tanh(k_s \dot{q}).$$

This model can be improved by considering possible parameters' asymmetries with respect to the joint velocity $\dot{q}$. In particular, the coulomb friction parameter k_c may depend on the sign of $\dot{q}$, and have different values depending on this sign. Then, an improved model is:

$$PWM = PWM_{\text{control}} + k_v \dot{q} + [k_{cp} s(\dot{q}) + k_{cn} s(-\dot{q})] \tanh(k_s \dot{q}),$$

where the function $s(x)$ is the step function, i.e.

$$s(x) = 1 \quad \text{if} \quad x >= 0; s(x) = 0 \quad \text{if} \quad x < 0.$$

As stated, the above equation constitutes the relation between the tension applied to the motor and the link torque. Then, to generate a desired torque τ_d coming from an higher control loop, it suffices to evaluate the above equation with $\tau = \tau_d$. In practice, however, it is a best practice to add a lower loop to generate τ so that τ will converge to τ_d, i.e:

$$PWM_{control} = k_{ff}\tau_d - k_p e_\tau - k_i \int e_\tau \mathrm{d}t,$$

where $e_\tau := \tau - \tau_d$.

This document was adapted from the documentation left over in the source code.