Arm Model

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1 Arm model

The plant is a two degrees-of-freedom (dofs) planar arm controlled by 6 muscles, illustrated in Fig. 1. There are several such models in the literature. The model described in [**?**] lies in the vertical plane so it takes the gravity force into account. Most other models are defined in the saggital plane and ignore gravity effects. They all combine a simple two dofs planar rigid-body dynamics model with a muscular actuation model. The differences between models mostly lie in the latter component.

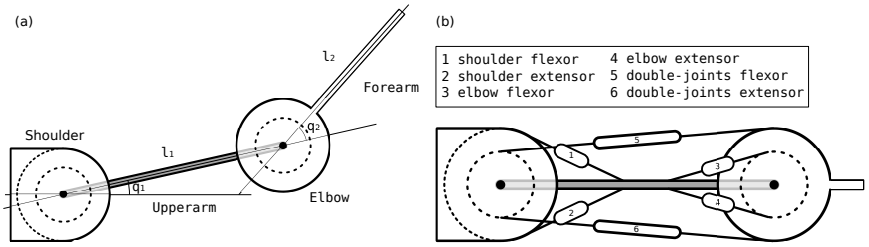

FIGURE 1 – Arm model. (a) Schematic view of the arm mechanics. (b) Schematic view of the muscular actuation of the arm, where each number represents a muscle whose name is in the box.

Table 3 in Appendix A reminds the nomenclature of all the parameters and variables of the arm model.

1.1 Arm parameters

We can find all parameters of the arm in the file *setupArmParameters*.

A Nomenclature of arm parameters

Références

TABLE 1 – Parameters of the arm model.

m_i	mass of segment i (kg)
l_i	length of segment i (m)
s_i	inertia of segment i $(kg.m^2)$
d_i	distance from the center of segment i to its center of mass (m)
κ	Heaviside filter parameter
$\mathbf{A}$	moment arm matrix $(\in \mathbb{R}^{6\times 2})$
$\mathbf{f_{max}}$	maximum muscular tension $(\in \mathbb{R}^6)$
$\mathbf{M}$	inertia matrix $(\in \mathbb{R}^{2\times 2})$
$\mathbf{C}$	Coriolis force $(N.m \in \mathbb{R}^2)$
τ	segments torque $(N.m \in \mathbb{R}^2)$
$\mathbf{B}$	damping term $(N.m \in \mathbb{R}^2)$
$\mathbf{u}$	raw muscular activation (action) $(\in [0,1]^6)$
σ_u^2	multiplicative muscular noise $(\in [0,1]^6)$
$\tilde{u}$	filtered noisy muscular activation $(\in [0,1]^6)$
$\mathbf{q}^*$	target articular position $(rad \in [0, 2\pi[^2)$
$\mathbf{q}$	current articular position $(rad \in [0, 2\pi[^2)$
$\dot{q}$	current articular speed $(rad.s^{-1})$
$\ddot{q}$	current articular acceleration $(rad.s^{-2})$

TABLE 2 – Parameters of the arm.

$\mathbf{l_1}$	arm length (m)	0.3
$\mathbf{l_2}$	forearm length (m)	0.35
$\mathbf{m_1}$	arm mass (kg)	1.4
$\mathbf{m_2}$	forearm mass (kg)	1.1
$\mathbf{s_1}$	arm inertia $(kg.m^2)$	0.11
$\mathbf{s_2}$	forearm inertia $(kg.m^2)$	0.16
$\mathbf{d_1}$	distance from the center of segment 1 to its center of mass (m)	0.025
$\mathbf{d_2}$	distance from the center of segment 2 to its center of mass (m)	0.045
$\mathbf{k_6}$	damping term	0.05
$\mathbf{k_7}$	damping term	0.025
$\mathbf{k_8}$	damping term	0.025
$\mathbf{k_9}$	damping term	0.05
$\mathbf{a_1}$	moment arm matrix	0.04
$\mathbf{a_2}$	moment arm matrix	-0.04
$\mathbf{a_3}$	moment arm matrix	0.0
$\mathbf{a_4}$	moment arm matrix	0.0
$\mathbf{a_5}$	moment arm matrix	0.028
$\mathbf{a_6}$	moment arm matrix	-0.035
$\mathbf{a_7}$	moment arm matrix	0.0
$\mathbf{a_8}$	moment arm matrix	0.0
$\mathbf{a_9}$	moment arm matrix	0.025
$\mathbf{a_{10}}$	moment arm matrix	-0.025
$\mathbf{a_{11}}$	moment arm matrix	0.028
$\mathbf{a_{12}}$	moment arm matrix	-0.035

TABLE 3 – Parameters of the muscles.

$\mathbf{f_{max1}}$	Maximum force exerted by the shoulder flexor	700
$\mathbf{f_{max2}}$	Maximum force exerted by the shoulder extensor	382
$\mathbf{f_{max3}}$	Maximum force exerted by the elbow flexor	572
$\mathbf{f_{max4}}$	Maximum force exerted by the elbow extensor	445
$\mathbf{f_{max5}}$	Maximum force exerted by the double-joints flexor	159
$\mathbf{f_{max6}}$	Maximum force exerted by the double-joints extensor	318