Arm Model

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5 mai 2015

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.

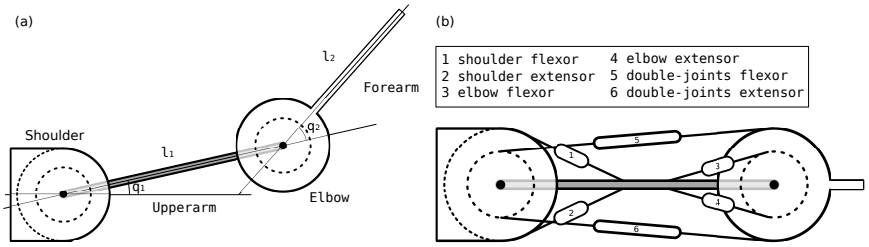

FIGURE 1 – Arm model. (a) Schematic view of the arm mechanics. (b) Schematic view of the muscular actuation of the arm, where each number represents a muscle whose name is in the box.

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
$\mathbf{l_2}$	arm mass (kg)	1.4
$\mathbf{l_2}$	forearm mass (kg)	1.1
$\mathbf{l_2}$	arm inertia $(kg.m^2)$	0.11
$\mathbf{l_2}$	forearm inertia $(kg.m^2)$	0.16
$\mathbf{l_2}$	distance from the center of segment 1 to its center of mass (m)	0.025
$\mathbf{l_2}$	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.

fmax1	Maximum force exerted by the shoulder flexor	700
fmax2	Maximum force exerted by the shoulder extensor	382
fmax3	Maximum force exerted by the elbow flexor	572
fmax4	Maximum force exerted by the elbow extensor	445
fmax5	Maximum force exerted by the double-joints flexor	159
fmax6	Maximum force exerted by the double-joints extensor	318