

A Bio-inspired Approach for Regulating and Measuring

Visco-elastic Properties of a Robot Arm

Position	α_{max} [N/m]	α_{min} [N/m]	ϕ [rad]	area [N ² /m ²]	K_{11} [N/m]	$K_{12}=K_{21}$ [N/m]	K_{22} [N/m]
1	253.5	24.8	2.23	19756.0	110.0	−110.5	168.2
2	213.8	25.9	2.17	17438.0	85.3	−87.3	154.4
3	208.6	26.0	2.04	17099.0	63.2	−73.5	171.4
4	201.7	26.7	1.92	16966.0	47.0	−56.0	181.3
5	262.6	24.7	1.68	20449.0	27.2	−24.0	260.1

Table 1: *Ellipse parameters for the compliance control in the joint space in the posture maintenance case ($K_P = \text{diag}\{32, 4.5\}$).*

Position	α_{max}	α_{min}	ϕ	area	K_{11}	$K_{12}=K_{21}$	K_{22}
	[N/m]	[N/m]	[rad]	[N ² /m ²]	[N/m]	[N/m]	[N/m]
1	253.5	24.8	2.23	19756.0	110.0	−110.5	168.2
2	249.8	24.9	2.24	19576.0	110.3	−109.1	164.4
3	230.7	24.7	2.27	17931.0	109.2	−101.3	146.2
4	180.0	23.9	2.19	13540.0	75.7	−73.5	128.2
5	178.2	24.1	2.11	13500.0	63.8	−67.3	138.5
6	172.4	25.6	1.96	13912.0	46.0	−50.7	152.1
7	190.5	25.5	1.80	15320.0	33.7	−35.8	182.3
8	261.7	24.8	1.68	20447.0	27.4	−24.6	259.1
9	262.6	24.7	1.68	20449.0	27.2	−24.0	260.1

Table 2: Ellipse parameters for the compliance control in the joint space in the dynamic case ($K_P = \text{diag}\{32, 4.5\}$).

Position	α_{max}	α_{min}	ϕ	area	K_{11}	$K_{12}=K_{21}$	K_{22}
	[N/m]	[N/m]	[rad]	[N ² /m ²]	[N/m]	[N/m]	[N/m]
1	124.1	12.9	2.21	5059.0	52.5	−53.2	84.6
2	105.5	13.6	2.14	4510.9	39.6	−41.4	79.4
3	102.3	13.7	2.02	4411.0	30.1	−34.4	85.8
4	101.0	13.9	1.90	4437.7	22.6	−26.0	92.3
5	128.8	12.9	1.66	5259.9	13.8	−9.7	128.0

Table 3: Ellipse parameters for the compliance control in the joint space in the posture maintenance case ($K_P = \text{diag}\{15, 2.5\}$).

Position	α_{max}	α_{min}	ϕ	area	K_{11}	$K_{12}=K_{21}$	K_{22}
	[N/m]	[N/m]	[rad]	[N ² /m ²]	[N/m]	[N/m]	[N/m]
1	124.1	12.9	2.21	5059.0	52.5	−53.2	84.6
2	124.9	12.9	2.21	5083.2	52.3	−53.5	85.5
3	63.2	9.5	2.41	1897.1	39.0	−26.7	33.7
4	67.5	10.5	2.27	2229.5	34.0	−28.0	43.9
5	62.2	10.9	2.17	2141.8	26.9	−23.7	46.2
6	70.0	12.2	1.97	2702.0	20.7	−20.3	61.5
7	79.9	13.2	1.80	3342.8	16.5	−14.3	76.7
8	134.2	12.8	1.64	5409.3	13.3	−7.7	133.7
9	128.8	12.9	1.66	5259.9	13.8	−9.7	128.0

Table 4: *Ellipse parameters for the compliance control in the joint space in the dynamic case ($K_P = \text{diag}\{15, 2.5\}$).*

Position	α_{max} [N/m]	α_{min} [N/m]	ϕ [rad]	area [N ² /m ²]	K_{11} [N/m]	$K_{12}=K_{21}$ [N/m]	K_{22} [N/m]
1	213.4	22.8	2.21	15316.0	89.6	−90.9	146.5
2	177.2	22.9	2.13	12763.0	66.3	−69.3	133.8
3	176.2	22.7	2.00	12623.0	48.6	−57.4	150.4
4	174.3	24.3	1.88	13343.0	37.6	−42.5	161.0
5	222.9	22.1	1.62	15504.0	22.5	−9.4	222.53

Table 5: *Ellipse parameters for the coactivation-based compliance control in the joint space in the posture maintenance case ($\alpha = 1$).*

Position	α_{max}	α_{min}	ϕ	area	K_{11}	$K_{12}=K_{21}$	K_{22}
	[N/m]	[N/m]	[rad]	[N ² /m ²]	[N/m]	[N/m]	[N/m]
1	203.4	21.4	2.21	13721.0	85	−86.7	139.9
2	213.4	22.8	2.21	15316.0	89.6	−90.9	146.5
3	164.8	26.6	2.23	13819.0	78.2	−66.8	113.2
4	187.0	29.1	2.10	17108.0	69.3	−68.8	146.8
5	181.3	27.7	1.96	15827.0	49.8	−53.9	159.2
6	203.5	29.8	1.81	19085.0	39.0	−39.0	194.3
7	197.2	23.3	1.68	14447.0	25.3	−18.7	195.1
8	222.9	22.1	1.62	15504	22.5	−9.4	222.53
9	209.0	21.0	1.63	13830.0	21.7	−11.0	208.41

Table 6: *Ellipse parameters for the coactivation-based compliance control in the joint space in the dynamic case ($\alpha = 1$).*

Position	α_{max}	α_{min}	ϕ	area	K_{11}	$K_{12}=K_{21}$	K_{22}
	[N/m]	[N/m]	[rad]	[N ² /m ²]	[N/m]	[N/m]	[N/m]
1	311.1	33.3	2.20	32585.0	126.8	−131.2	217.6
2	265.1	34.3	2.11	24641.0	95.1	−1016	204.3
3	256.9	34.4	2.00	27841.0	71.3	−82.7	220.0
4	253.2	35.1	1.84	27989.0	50.2	−55.2	238.1
5	310.9	31.7	1.64	30982.0	32.8	−18.0	309.8

Table 7: *Ellipse parameters for the coactivation-based compliance control in the joint space in the posture maintenance case ($\alpha = 2$).*

Position	α_{max}	α_{min}	ϕ	area	K_{11}	$K_{12}=K_{21}$	K_{22}
	[N/m]	[N/m]	[rad]	[N ² /m ²]	[N/m]	[N/m]	[N/m]
1	311.1	33.3	2.20	32585.0	126.8	-131.2	217.6
2	310.4	31.9	2.19	31114.0	123.7	-130.9	218.5
3	237.8	32.3	2.23	24173.0	108.0	-99.1	162.0
4	218.6	33.1	2.11	22764.0	82.1	-81.8	169.6
5	239.6	36.3	1.96	27361.0	64.8	-70.5	211.1
6	249.4	35.9	1.81	28174.0	47.5	-48.4	237.8
7	285.4	34.3	1.71	30818.0	39.0	-33.8	280.7
8	334.4	32.5	1.62	34153.0	33.1	-13.7	333.8
9	310.9	31.7	1.64	30982.0	32.8	-18.0	309.8

Table 8: *Ellipse parameters for the coactivation-based compliance control in the joint space in the dynamic case ($\alpha = 2$).*