3-FINGER ADAPTIVE ROBOT GRIPPER

SIMULATION DATA

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The following document provides the necessary information so that you can create a simulation of the 3-Finger Adaptive Gripper fingers. Some data has been measured experimentally and other data is taken from the Gripper CAD.

1. Finger Geometry

Figure 1 shows the nomenclature that has been given to the finger parts. Take note that the different screws and axes are not part of the nomenclature, although, they have been considered in the inertia calculations for the part. Some hardware pieces have been considered as uniform when they were solidly attached to each other. For example: a shaft/pin that is press-fitted on a hinge is considered as being part of the hinge.

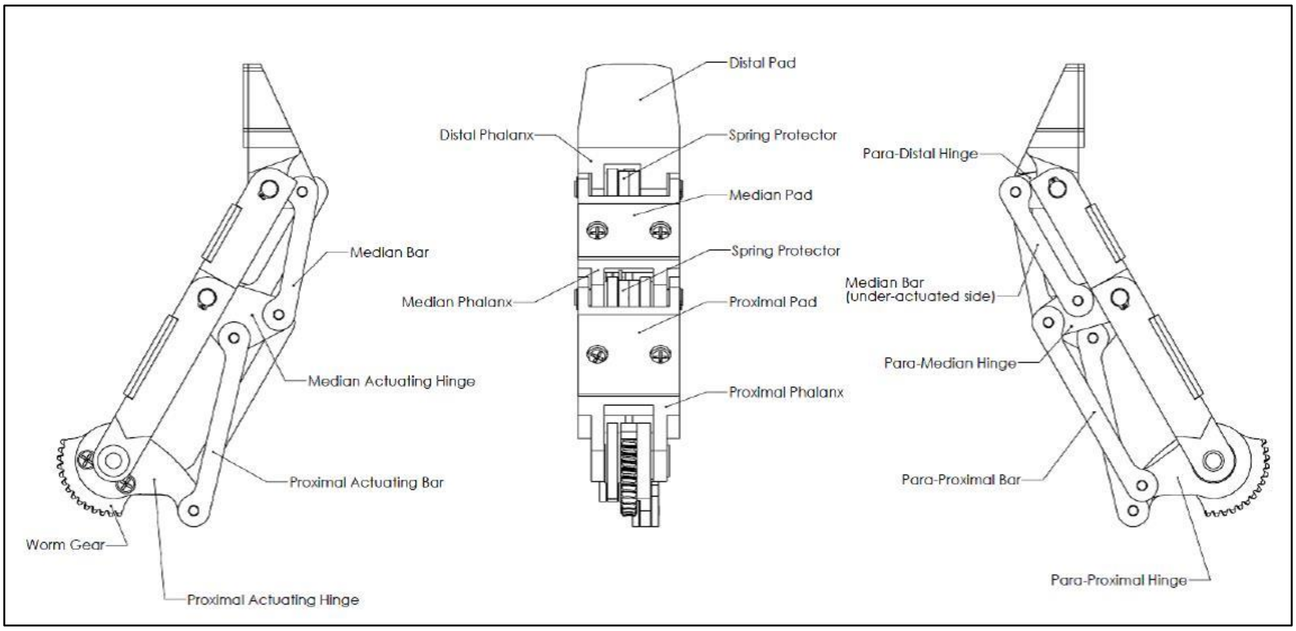

Figure 1 : 3-Finger Adaptive Gripper finger nomenclature

See Appendix 1 for finger data

Coordinate System

The following Figure shows the coordinate system for the bars and parts of the mechanism. The Z-axis is always on the first pivot axis of the part (in the Kinematic chain) with the direction being set such that a positive rotation along the Z-axis of the Proximal Actuating Hinge will perform a closing motion with the finger (the direction of the Z-axis is the same for all parts). The X-axis is pointing towards the axis of another pivot located on the same part (please refer to Figure 2). The only exception is the distal phalanx for which the X-axis is parallel to the gripping pad surface. In all cases, the Y-axis follows from the X-axis and Z-axis according to the right-hand convention. The finger's coordinate system (C.S.) is presented in Figure 2.

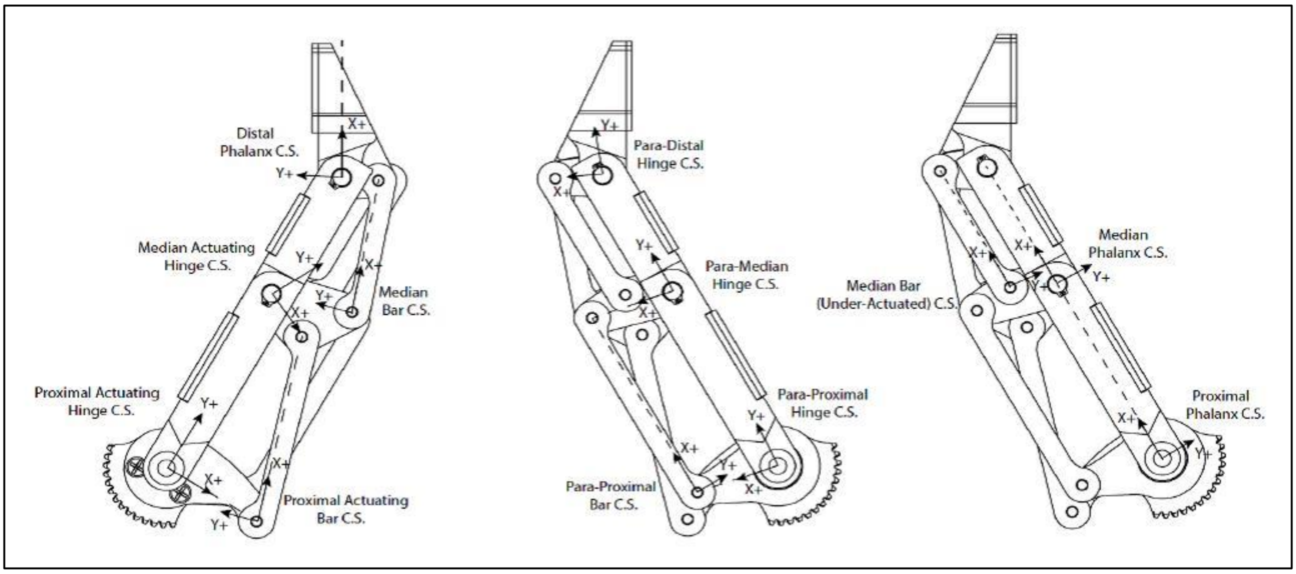

Figure 2: Robotiq 3-Finger Adaptive Gripper coordinate system configuration

Notice that Appendix 1 includes the position of the second and third pivot for each part.

Finger Nomenclature

The Adaptive Gripper has three articulated fingers, i.e. Finger A in front of Finger B and Finger C, and each finger has three joints (three phalanxes per finger), as shown in Figure 2. The Gripper can engage up to ten points of contact with an object (three on each of the phalanges plus the palm). The fingers are under-actuated, meaning they have fewer motors than the total number of joints. This configuration allows the fingers to automatically adapt to the shape of the object they grip and it also simplifies the control of the Gripper. Figure 3 shows the Gripper fingers' configuration.

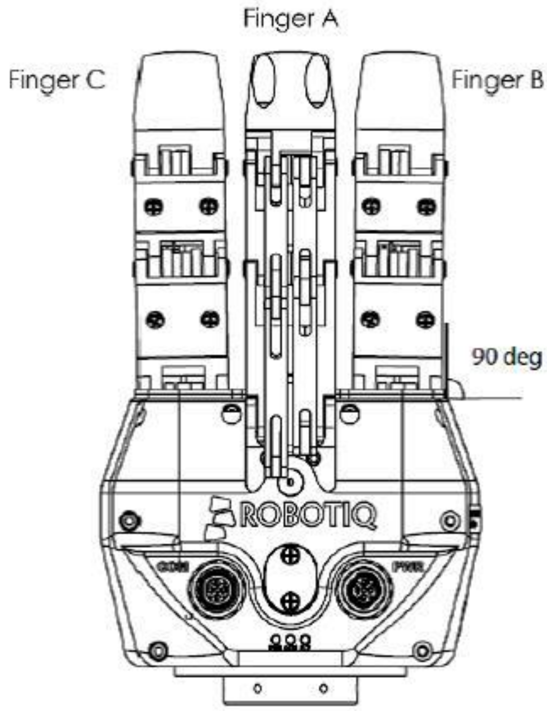

Figure 3: Robotiq 3-Finger Adaptive Gripper finger configuration

Position Nomenclature

There are 3 intermediate positions. The first is the basic mode, where the fingers are perpendicular (90°) to the palm. Fingers B and C can act in a pinch mode. This mode rotates at the basis of the fingers and gives the fingertips a bigger (wide mode) or smaller (pinch mode) grip on an object. The wide mode is when Fingers B and C are at a 74° angle to the palm and the pinch mode is when Fingers B and C make a 110° angle with the palm.

2. HD Parameters

In order to simulate the kinematics of the Robotiq 3-Finger Adaptive Robot Gripper, you can use the Hartenberg-Denavit parameters listed in Table 1. The related reference points are shown in Figure 4.

Table 1: Hartenberg-Denavit Parameters for the Robotiq 3-Finger Adaptive Gripper

	Finger A				Finger B				Finger C			
i	a_{Ai} [mm]	b_{Ai} [mm]	α_{Ai} [deg]	θ_{Ai} [deg]	a_{Bi} [mm]	b_{Bi} [mm]	α_{Bi} [deg]	θ_{Bi} [deg]	a_{Ci} [mm]	b_{Ci} [mm]	α_{Ci} [deg]	θ_{Ci} [deg]
1	0	61.112	90	-90	36.525	61.112	90	90	36.525	61.112	-90	-90
2	21.514	-44.475	90	90	21.514	-44.780	90	[74, 100]	21.514	-44.780	90	-[74, 100]
3	57.150	0	0	[-35, 35]	57.150	0	0	[-35,35]	57.150	0	0	[-35, 35]
4	38.100	0	0	[0, 90]	38.100	0	0	[0, 90]	38.100	0	0	[0, 90]
5	38.100	0	0	[-25, 73]	38.100	0	0	[-25, 73]	38.100	0	0	[-25, 73]

3. Spring Data

Two torsion springs are used per finger in the 3-Finger Adaptive Gripper. One is located by the median axis connecting the Proximal Phalanx and the Median Phalanx. The second one is by the distal axis connecting the Distal Phalanx and the Median Phalanx. The springs tighten as the finger closes.

The springs used in the 3-Finger Adaptive Gripper are from *Ressorts Spec*, model T030270250XL. The spring is composed of a 0.76mm wire with a 270° rotational configuration. Concerning the torque of the spring, the manufacturer claims a torque of 39.45N/mm for a 119° rotational configuration. Both spring ends being at 110° from each other with a preloaded tension of approximately 41.8 N/mm.

Although uncertainties concerning the friction and even the supplier batch can vary the spring accuracy slightly.

4. Motor Data

The motors used for the grasping (rPRA, rPRB, rPRC) and scissoring (rPRS) actions are Faulher 2232V0124 DC, brushed. It has a 20:1 planetary gearhead ratio with a reduction ratio of 14:1. The motor position is returned to the robot as a variable integer ranging from 0 to 255 (gPOA, gPOB, gPOC). Position 0 (gPOx = 0) is defined as the motor position for which the mechanical stop is reached during the activation procedure. Position 240 (gPOx = 240) is defined as the position for which the finger touches the palm during the activation procedure.

5. Gearing Data

At the end of the grasping motor rotating shaft, an endless screw transfers the rotation to a worm gear that is fixed to the Proximal Actuating Hinge. The ratio between the endless screw and the worm gear is 40:1. The scissor motor activates the endless screw to rotate Fingers B and C (wide or pinch mode) at the same rotating rate. The situation which represents the basic mode for the fingers is consider to be a 90° angle rotation and a 0 degree motor rotation. To get to the wide mode position (74°) a single finger has to rotate -16°. In the pinch mode (110°), a single finger has to rotate 20° from its basic mode position.

Equation 1 represents the angle variation of the finger depending on the amount of motor rotation. A positive amount of rotations will close the fingers together and a negative amount will open them.

$$\Delta\theta_{finger} = tan^{-1}\left[\frac{1.27\ (x\ motor\ rotation)}{34.92}\right] \qquad \text{Eq. 1}$$

The angle is measured at the rotation point of the finger. During calibration, the value of 0 is given to the fully opened position/wide mode (mechanical stop), whereas 220 is given to the fully closed position/pinch mode (fingers touching each other).

6. Force Data

The closing force of the fingers is controlled by using a variable integer ranging from 0 to 255. The maximum current in the motor for a grasping motion (rFRA, rFRB, rFRC) goes from 225mA to 590mA using a linear relation. The maximum current in the motor for a scissoring motion (rFRS) uses the same value range, but the current range of the motor goes from 225mA to 460mA using a linear relation.

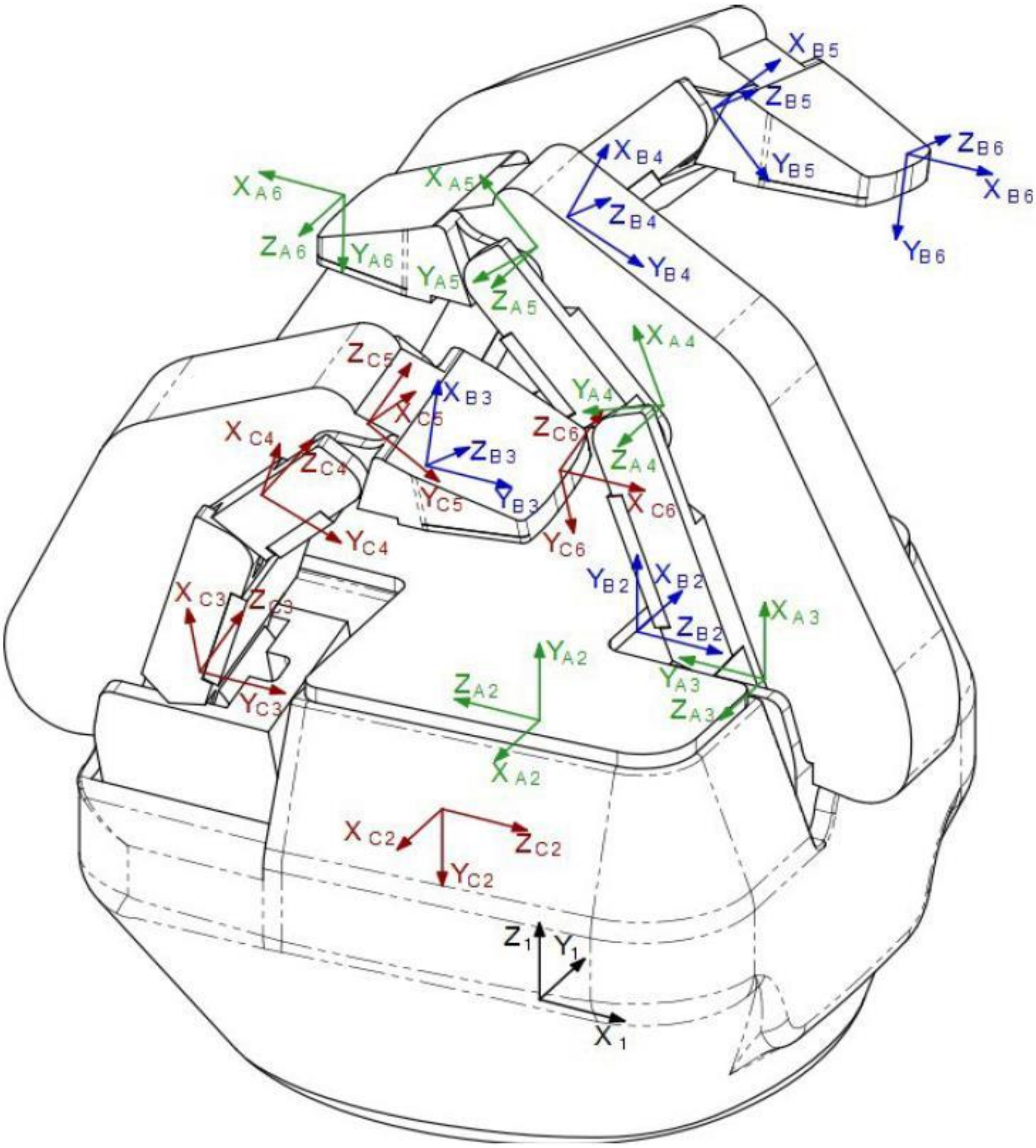

Figure 4: Hartenberg-Denavit diagram for the Robotiq 3-Finger Adaptive Gripper

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Appendix 1

Geometry and weights for the 3-Finger Adaptive Gripper fingers

Name	Weight [g]	Moment of inertia [g*mm2]			Center of mass [mm]		Data Includes	Second Pivot Location [mm]		Third Pivot Location [mm]	
Proximal Phalanx											
Proximal Phalanx (With Pad)	47.00	Ixx = 4993.32	Ixy = 913.12	Ixz = -1.20	X	32.180	large axis + pad + 2 screws	X	57.15	X	N/A
		Iyx = 913.12	Iyy = 64345.31	Iyz = -0.07	Y	0.530		Y	0.00	Y	N/A
		Izx = -1.20	Izy = -0.07	Izz = 60619.17	Z	0.000					
Proximal Phalanx	40.52	Ixx = 4273.38	Ixy = -321.96	Ixz = -1.20	X	32.040	large axis	X	57.15	X	N/A
		Iyx = -321.96	Iyy = 56331.75	Iyz = -0.07	Y	-0.300		Y	0.00	Y	N/A
		Izx = -1.20	Izy = -0.07	Izz = 52879.83	Z	0.000					
Proximal Actuating Hinge	26.47	Ixx = 1564.47	Ixy = 236.26	Ixz = 148.62	X	1.020	3 screws + worm gear	X	28.58	X	N/A
		Iyx = 236.26	Iyy = 2210.68	Iyz = 143.69	Y	-1.620		Y	0.00	Y	N/A
		Izx = 148.62	Izy = 143.69	Izz = 3231.75	Z	-1.610					
Proximal Actuating Bar	6.59	Ixx = 83.48	Ixy = -217.90	Ixz = 1.34	X	26.990	2 short axis	X	53.98	X	N/A
		Iyx = -217.90	Iyy = 7190.76	Iyz = 0.00	Y	-1.220		Y	0.00	Y	N/A
		Izx = 1.34	Izy = 0.00	Izz = 7182.72	Z	0.000					
Para-Proximal Hinge	3.62	Ixx = 120.43	Ixy = 0.00	Ixz = 0.00	X	6.400	N/A	X	22.86	X	N/A
		Iyx = 0.00	Iyy = 538.88	Iyz = 0.00	Y	0.000		Y	0.00	Y	N/A
		Izx = 0.00	Izy = 0.00	Izz = 653.22	Z	0.000					
Para-Proximal Bar	7.32	Ixx = 90.65	Ixy = -270.47	Ixz = 1.42	X	28.580	2 short axis	X	57.70	X	N/A
		Iyx = -270.47	Iyy = 8780.34	Iyz = 0.00	Y	-1.290		Y	0.00	Y	N/A
		Izx = 1.42	Izy = 0.00	Izz = 8774.58	Z	0.000					
Median Phalanx											
Median Phalanx (With Pad)	32.84	Ixx = 3480.08	Ixy = 319.40	Ixz = 130.41	X	21.67	large axis + pad + 2 screws	X	38.10	X	N/A
		Iyx = 319.40	Iyy = 22481.23	Iyz = 2.91	Y	0.48		Y	0.00	Y	N/A
		Izx = 130.41	Izy = 2.91	Izz = 19863.46	Z	0.18					
Median Phalanx	28.56	Ixx = 3005.80	Ixy = -153.54	Ixz = 115.23	X	22.03	large axis	X	38.10	X	N/A
		Iyx = -153.54	Iyy = 20426.77	Iyz = -1.59	Y	-0.30		Y	0.00	Y	N/A
		Izx = 115.23	Izy = -1.59	Izz = 17991.29	Z	0.18					
Median Actuating Hinge	3.59	Ixx = 247.35	Ixy = 236.19	Ixz = 0.00	X	9.20	N/A	X	14.73	X	16.25
		Iyx = 236.19	Iyy = 476.81	Iyz = 0.00	Y	5.14		Y	0.00	Y	15.16
		Izx = 0.00	Izy = 0.00	Izz = 718.13	Z	0.00					
Median Bar	5.38	Ixx = 66.39	Ixy = -109.96	Ixz = 0.94	X	19.05	2 short axis	X	38.10	X	N/A
		Iyx = -109.96	Iyy = 3053.18	Iyz = 0.00	Y	-1.07		Y	0.00	Y	N/A
		Izx = 0.94	Izy = 0.00	Izz = 3046.57	Z	0.00					
Median Bar (under-actuated side)	5.38	Ixx = 66.39	Ixy = -109.96	Ixz = 0.94	X	19.05	2 short axis	X	38.10	X	N/A
		Iyx = -109.96	Iyy = 3053.18	Iyz = 0.00	Y	-1.07		Y	0.00	Y	N/A
		Izx = 0.94	Izy = 0.00	Izz = 3046.57	Z	0.00					
Para-Median Hinge	2.76	Ixx = 42.13	Ixy = -14.91	Ixz = 0.00	X	-10.25	N/A	X	22.86	X	12.27
		Iyx = -14.91	Iyy = 502.58	Iyz = 0.00	Y	0.46		Y	0.00	Y	3.29
		Izx = 0.00	Izy = 0.00	Izz = 540.07	Z	0.00					
Distal Phalanx											
Distal Phalanx (With Pad)	33.54	Ixx = 3051.51	Ixy = 897.92	Ixz = 2.49	X	16.26	Pad + 2 screws	X	N/A	X	N/A
		Iyx = 897.92	Iyy = 14279.78	Iyz = -11.91	Y	0.49		Y	N/A	Y	N/A
		Izx = 2.49	Izy = -11.91	Izz = 12641.26	Z	0.2					
Distal Phalanx	11.56	Ixx = 1089.46	Ixy = -104.70	Ixz = 2.52	X	6.45	N/A	X	N/A	X	N/A
		Iyx = -104.70	Iyy = 1546.60	Iyz = -11.91	Y	-1.45		Y	N/A	Y	N/A
		Izx = 2.52	Izy = -11.91	Izz = 1074.22	Z	0.59					
Para-Distal Hinge	1.58	Ixx = 19.07	Ixy = 0.00	Ixz = 0.00	X	5.48	N/A	X	12.70	X	N/A
		Iyx = 0.00	Iyy = 109.70	Iyz = 0.00	Y	0.00		Y	0.00	Y	N/A
		Izx = 0.00	Izy = 0.00	Izz = 126.10	Z	0.00					
General											
Short Axis	0.49	Ixx = 2.84	Ixy = 0.00	Ixz = 0.00	X	0.00	N/A	N/A		N/A	
		Iyx = 0.00	Iyy = 2.84	Iyz = 0.00	Y	0.00					
		Izx = 0.00	Izy = 0.00	Izz = 0.61	Z	0.00					
Long Axis	4.51	Ixx = 402.90	Ixy = 0.00	Ixz = 0.00	X	0.00	N/A	N/A		N/A	
		Iyx = 0.00	Iyy = 402.90	Iyz = 0.00	Y	0.00					
		Izx = 0.00	Izy = 0.00	Izz = 12.75	Z	0.00					
Worm Gear	19.90	Ixx = 933.35	Ixy = -107.26	Ixz = -0.03	X	-2.580	N/A	N/A		N/A	
		Iyx = -107.26	Iyy = 1143.31	Iyz = -0.09	Y	1.000					
		Izx = -0.03	Izy = -0.09	Izz = 1922.78	Z	-0.450					