

UNDERACTUATED HAND MODELING PROTOCOL

Reference No / Version	P1-v1.0																																																																
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Purpose	Evaluate a data-driven model of an underactuated hand to accurately predict in-hand manipulation with different objects and variations in the system.																																																																
Task Description	Predict a state-trajectory of the hand given a start state and a sequence of actions.																																																																
Setup Description	<p><u>List of objects and their descriptions:</u> All objects used are 3D printed with PLA, and have a height of 65mm with the following profile:</p> <table><tr><th></th><th>Profile/Object</th><th>Description</th><th>Abbreviation</th></tr><tr><td>1</td><td>Circular</td><td>$\varnothing 30mm$</td><td>cyl30</td></tr><tr><td>2</td><td>Circular</td><td>$\varnothing 35mm$</td><td>cyl35</td></tr><tr><td>3</td><td>Circular</td><td>$\varnothing 45mm$</td><td>cyl45</td></tr><tr><td>4</td><td>Square</td><td>$30mm \times 30mm$</td><td>sqr30</td></tr><tr><td>5</td><td>Reg. decagon</td><td>Circumscribed circle $\varnothing 42mm$</td><td>poly10</td></tr><tr><td>6</td><td>Reg. hexagon</td><td>Circumscribed circle $\varnothing 40mm$</td><td>poly6</td></tr><tr><td>7</td><td>Reg. triangle</td><td>Edge length $50mm$</td><td>tri50</td></tr><tr><td>8</td><td>Rectangle</td><td>$30mm \times 60mm$</td><td>rec60</td></tr><tr><td>9</td><td>Rectangle</td><td>$10mm \times 60mm$</td><td>rec10</td></tr><tr><td>10</td><td>Hexagram</td><td>Circumscribed circle $\varnothing 40mm$</td><td>str40</td></tr><tr><td>11</td><td>Egg</td><td>H. 52 mm, Max. W. $45mm$</td><td>egg50</td></tr><tr><td>12</td><td>Ellipse</td><td>$25mm \times 40\text{ mm}$</td><td>elp40</td></tr><tr><td>13</td><td>Crescent</td><td>Outer $\varnothing 55mm$, inner $\varnothing 45mm$</td><td>cre55</td></tr><tr><td>14</td><td>Semi-circular</td><td>$\varnothing 60mm$</td><td>sem60</td></tr><tr><td>15</td><td>Box</td><td>$30mm \times 60mm \times 65mm$</td><td>box60</td></tr></table> <p>Profile drawings are included in the designated website https://github.com/avishais/underactuated_hand_benchmarking.</p> <p><u>Description of the manipulation environment:</u></p> <p>All objects have a fiducial marker in the geometric center of the profile.</p> <p><u>Initial and target poses of the objects:</u></p> <p>When grasping, position the center of the object in the grasp region (defined below) and close the fingers.</p>		Profile/Object	Description	Abbreviation	1	Circular	$\varnothing 30mm$	cyl30	2	Circular	$\varnothing 35mm$	cyl35	3	Circular	$\varnothing 45mm$	cyl45	4	Square	$30mm \times 30mm$	sqr30	5	Reg. decagon	Circumscribed circle $\varnothing 42mm$	poly10	6	Reg. hexagon	Circumscribed circle $\varnothing 40mm$	poly6	7	Reg. triangle	Edge length $50mm$	tri50	8	Rectangle	$30mm \times 60mm$	rec60	9	Rectangle	$10mm \times 60mm$	rec10	10	Hexagram	Circumscribed circle $\varnothing 40mm$	str40	11	Egg	H. 52 mm , Max. W. $45mm$	egg50	12	Ellipse	$25mm \times 40\text{ mm}$	elp40	13	Crescent	Outer $\varnothing 55mm$, inner $\varnothing 45mm$	cre55	14	Semi-circular	$\varnothing 60mm$	sem60	15	Box	$30mm \times 60mm \times 65mm$	box60
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Robot/Hardware/Software/S object Description	<p><u>Targeted robots/hardware/software:</u> Underactuated robotic hand 2-fingers Model T42 or 3-fingers Model O (can be downloaded and printed in https://www.eng.yale.edu/grablab/openhand/).</p> <p>Model T42:</p> <ul style="list-style-type: none">• Should be mounted such that plane of motion of the two fingers is parallel to the ground.• A base marker is positioned on the left swivel.• Markers are also positioned on the fingers. <p>Model O:</p> <ul style="list-style-type: none">• Positioned such that the fingers point upward.• A base marker is positioned on the plate between the fingers or next to the hand.																																																																

	<p>A camera is positioned above such that it measures the pose of the object marker relative to the base marker.</p> <p>Action commands are given in 2.5Hz while recording of data is done in 10 Hz.</p> <p>An action is the change of angles of the actuators. That is, an action moves actuator i with an angle of $\lambda * \gamma$, where λ is a predefined unit angle set to 0.1924° and γ is in the range $[-1, 1]$.</p> <p><u>Initial state of the robot/hardware/subject with respect to the setup:</u></p> <p>The fingers should be calibrated such that they close at the same time and meet at the middle, within a range (termed <i>grasp region</i>) of 10mm from the center plane.</p> <p><u>Prior information provided to the robot:</u></p> <ul style="list-style-type: none"> • Set of available actions in the discrete case, or range of actions in the continuous case. • Data-driven model. • Action sequences. <p>These are defined in the appendix and the website.</p>
Procedure	
Execution Constraints	<p>Overload is defined when any of the actuators load reach above 270 (in Dynamixel units).</p>