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Improving the Techniques for Center of Mass Estimation Using Statically Equivalent Serial Chain Modeling

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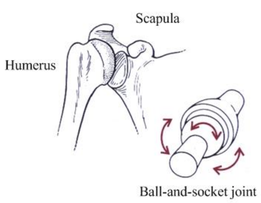
Objectives

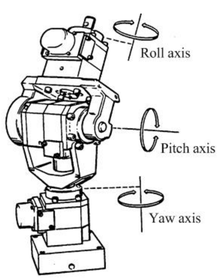
1. To experimentally validate the Statically Equivalent Serial Chain (SESC) Modeling Theory. 2. To investigate the minimum amount of data required to construct a usable SESC. 3. To investigate the SESC modeling for systems that have one or more stationary segments.

Motivation/Introduction

Identifying the center of mass (CoM) is critical in robotics and the life sciences.

The SESC is a virtual serial chain representation of a system which is composed of rigid links articulated by revolute and/or spherical joints. The terminus of the SESC points at the CoM of the system, thus it predicts the system's CoM for any configuration, given only additional information of joint angles for that configuration.

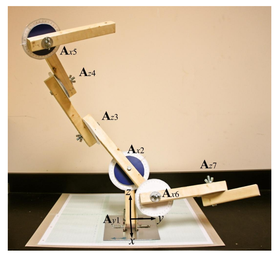




Experimental Validation

The experimental model was composed of 7 links articulated with revolute joints formed by wing nuts and bolts.

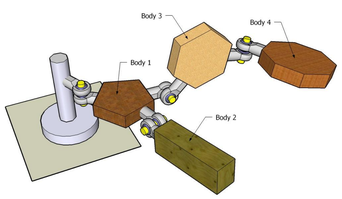
1. Based on the rotation axes of the joints in the system, the kinematic form of the SESC was determined.
2. 2D CoM data and joint angles were measured at 26 various configurations.
3. The SESC model was derived using the experimental data.
4. Given joint angles for another 10 configurations, 3D CoM locations were predicted using the SESC model.
5. The predicted CoM were compared to the measured CoM.



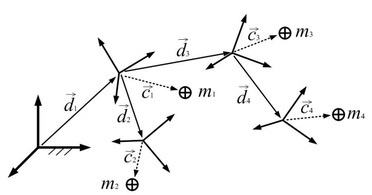
An experimental model of an articulated branched-chain system.

Configuration	Predicted CoM (mm)			Measured CoM (mm)			Prediction Error (mm)		
	X	Y	Z	X	Y	Z	X	Y	Z
1	-19.24	-23.50	193.32	-22.5	-25.5	195	3.3	2.0	-2
2	-13.77	15.53	157.46	-16.3	18.3	155	2.5	-2.8	2
3	81.90	36.36	176.22	76.5	37.7	175	5.4	-1.3	1
4	44.72	-14.62	183.87	43.0	-19.8	188	1.7	5.2	-4
5	44.23	-28.88	197.95	45.0	-24.5	200	-0.8	-4.4	-2
6	0.29	3.15	200.74	0.5	2.0	201	-0.2	1.2	0
7	73.39	-60.21	232.23	75.8	-58.8	228	-2.4	-1.4	4
8	9.60	4.28	201.99	8.8	4.8	205	0.8	-0.5	-3
9	1.69	-10.18	225.02	2.2	-12.5	220	-0.5	2.3	5
10	33.35	36.41	196.99	35.0	40.2	200	-1.6	-3.8	-3

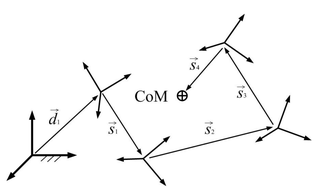
The CoM predicted using SESC modeling vs. the measured CoM



A branched-chain system composed of 4 articulated rigid bodies.



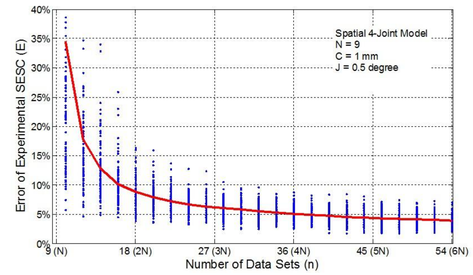
The static structure of the system with the parameters identified to locate its center of mass.



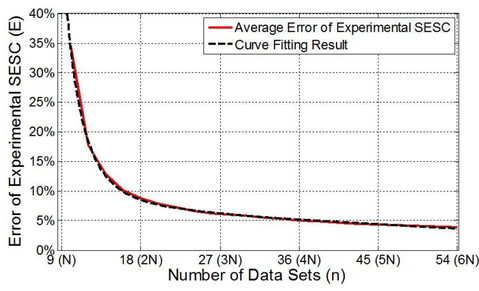
The SESC model of the branched chain system.

The Estimated Error of Experimental SESC Model

Investigating the estimated error of the experimental SESC model helps understanding the minimum amount of data needed before the SESC model obtains accuracy.

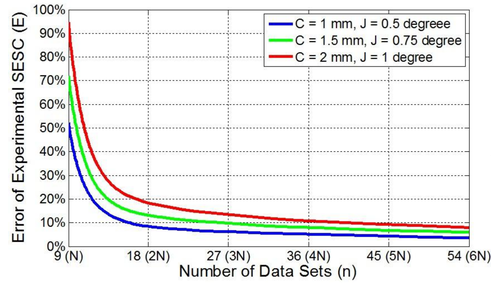


Estimated error of the SESC model of a virtual system derived using data with error.



A curve fitting of the result using:

$E_e = an^b + ce^{dn}$



Estimated error of experimental SESC derived from data with different ranges of error.