Dynamic Arm Simulator (DAS3)

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SimTK project: https://simtk.org/home/das
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Introduction

DAS3 is the third generation of the Dynamic Arm Simulator, a real-time simulator of a musculoskeletal model of the shoulder and arm. The first generation (DAS1) was a planar arm with two degrees of freedom and six muscles [1]. The next generation (DAS2) was 3D and had five degrees of freedom and 102 muscle elements [2]. It had the limitation that the scapula could not move relative to the thorax. DAS3 has a complete shoulder girdle controlled by muscle forces and contact with the thorax [3].

The model represents the right shoulder and arm, and contains the following segments: thorax, which is fixed, clavicle, scapula, humerus, ulna, radius, and hand (fixed to the radius). It has eleven degrees of freedom: three at the sternoclavicular joint (clavicle protraction/retraction, elevation/depression, axial rotation), three at the acromioclavicular joint (scapula protraction/retraction, lateral/medial rotation, tilt), three at the glenohumeral joint (humerus plane of elevation, elevation angle, axial rotation), elbow flexion/extension and forearm pronation/supination.

The DAS3 model has 29 muscles, divided into 138 elements:

No.	Muscle name	First element	Last element
1	Trapezius, scapular part	1	11
2	Trapezius, clavicular part	12	13
3	Levator Scapulae	14	15
4	Pectoralis Minor	16	19
5	Rhomboid	20	24
6	Serratus Anterior	25	36
7	Deltoid, scapular part	37	47
8	Deltoid, clavicular part	48	51

9	Coracobrachialis	52	54
10	Infraspinatus	55	60
11	Teres Minor	61	63
12	Teres Major	64	67
13	Supraspinatus	68	71
14	Subscapularis	72	82
15	Biceps, long	83	83
16	Biceps, short	84	85
17	Triceps, long	86	89
18	Latissimus Dorsi	90	95
19	Pectoralis Major, thoracic part	96	101
20	Pectoralis Major, clavicular part	102	103
21	Triceps, medial	104	108
22	Brachialis	109	115
23	Brachioradialis	116	118
24	Pronator Teres, humerus-radius	119	119
25	Pronator Teres, ulna-radius	120	120
26	Supinator	121	125
27	Pronator Quadratus	126	128
28	Triceps, lateral	129	133
29	Anconeus	134	138

For details on the model construction and the numerical methods used for the real-time simulation please see [3]. The model is suitable for solving optimal control problems (using methods such as described in [4]). A future release will include examples of such work.

Files included in the release

The software used to create and test the following files were 32-bit Opensim 3.2, 32-bit Matlab 2014a and Microsoft Windows SDK v.7.1. Please note that the current version of the real-time model only runs on 32-bit Matlab.

You should start with “das3sim.m” which shows the basic steps of running DAS3. It runs a simple simulation (using made-up muscle excitations) using the default time step of 3ms and times it. It prints out the CPU time needed for each time step, so it will allow you to determine if your computer is fast enough for DAS3 to run in real time. If the CPU time needed for each time step is more than 3ms, you can increase the model time step to increase the speed of the simulation, but keep in mind that a large time step will cause the model to be unstable.

The files included in the release are:

Opensim:

- das3.osim and geometry files: the Opensim model used to generate the real-time model and visualize the results of real-time simulations

Real-time model:

- das3mex.mexw32: the MEX function that calculates the system dynamics equation and its Jacobians (for details please see [3]). It calculates a number of other outputs as well, described in detail in das3mex.m.
- das3mex.m: a file that documents the use of the MEX function das3mex.mexw32
- das3step.m: the function that calls the MEX function and advances the forward simulation by one step using the Rosenbrock method (for details please see [3] and [4])
- das3.bio: a text file containing joint and muscle parameters that is read by the MEX function at runtime.
- equilibrium.mat: passive equilibrium state, used as the initial state in example simulations

Example applications:

- das3sim.m: simulates a simple movement using das3step, times it, plots the resulting angles and stores the results in a Matlab .mat file and an Opensim motion file
- driver.m and driver.fig: a graphical user interface (GUI) that allows you to interact with a real-time simulation by using sliders to change the muscle excitation patterns, and visualize the results using the Opensim Visualizer. For this to run you need to access the Opensim API through the Matlab scripting environment, following these instructions:
  http://simtk-confluence.stanford.edu:8080/display/OpenSim/Scripting+with+Matlab
  This application is set up to run 10 times slower than real time, and will update the Opensim visualization every 0.3 seconds. If your system is fast enough, you can alter these settings. Please note that when you hit “Start” the model is at passive equilibrium and will not move until you increase one of the muscle group activations.

References

1. Blana D., Kirsch R.F. and Chadwick E.K. Combined feedforward and feedback control of a redundant, nonlinear, dynamic musculoskeletal system. *Med Biol Eng Comput. 47(5):533-42*, 2009.
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4. van den Bogert A.J., Blana D. and Heinrich D. Implicit methods for efficient musculoskeletal simulation and optimal control, *Procedia IUTAM, IUTAM Symposium on Human Body Dynamics, 2:297-316,* 2011.