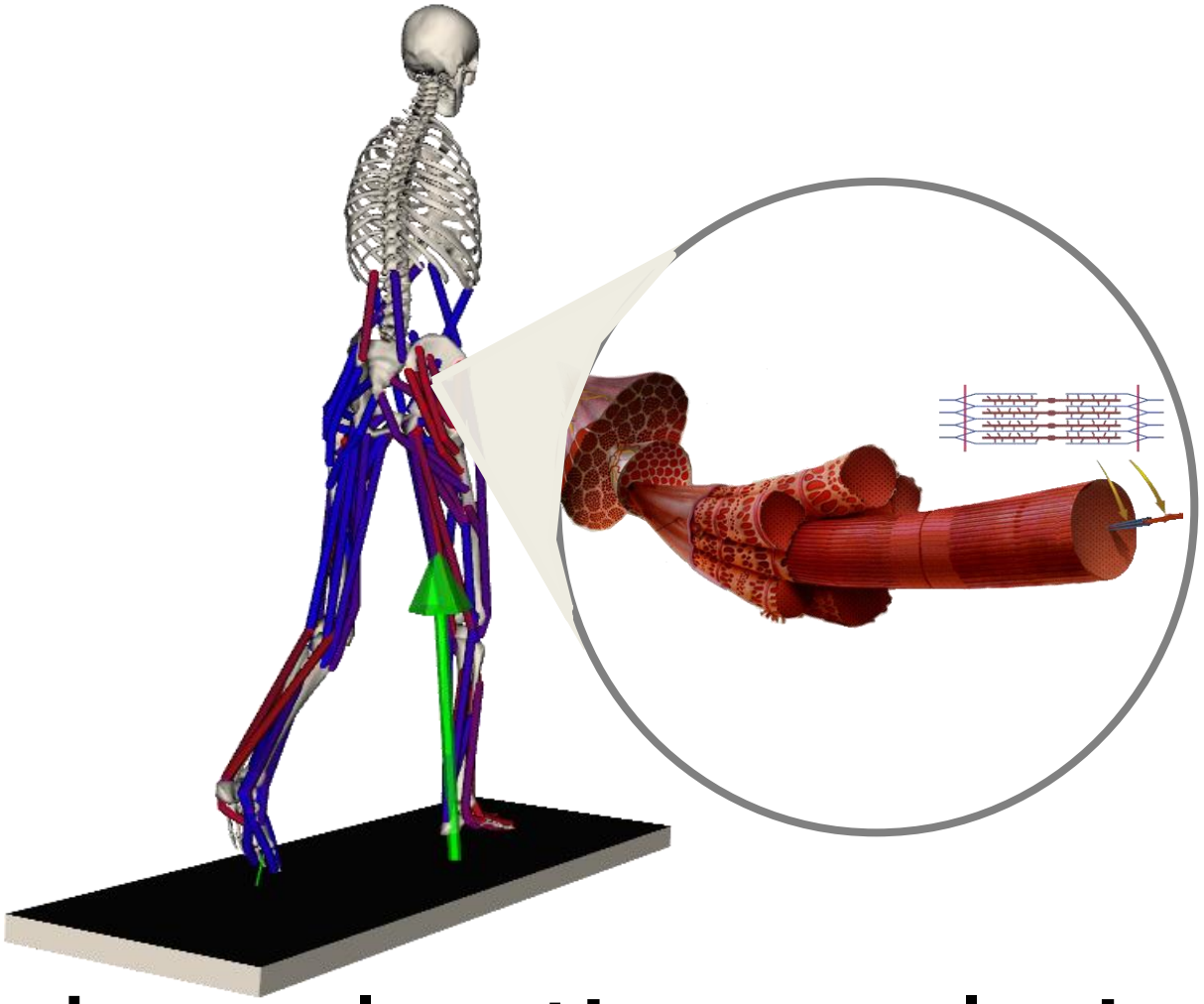


Induced acceleration analysis

OpenSim Workshop

Induced Acceleration Analysis

Equations of motion

$$[M]\ddot{q} = G(q) + V(q,\dot{q}) + S(q,\dot{q}) + [R]f$$

M: Mass matrix
Q: Generalized coordinates
G: Gravity
V: Coriolis and centrifugal effects
S: Generalized force due to contact elements
F: Generalized force (muscle force)
R: Force transformation matrix (moment arms)

Induced Acceleration Analysis

PERTURBATION	INDUCED ACCELERATION
Perturb muscle force (1N) and study effect on COM acceleration	
Forward integration over 0.03s	
Computationally expensive (days)	
Sensitive to contact stiffness Sensitive to time interval	
OpenSim 2.4	
Liu, 2006	

- Stiff 3D linear and torsional springs approximate a weld constraint

Induced Acceleration Analysis

PERTURBATION	INDUCED ACCELERATION
Perturb muscle force (1N) and study effect on COM acceleration	
Forward integration over 0.03s	Instantaneous effect
Computationally expensive (days)	Computationally efficient (minutes)
Sensitive to contact stiffness Sensitive to time interval	
OpenSim 2.4	OpenSim 3.0 onwards
Liu, 2006	

- Replaces the contribution of contact with an appropriate kinematic constraint.
- Kinematic constraint reaction forces are resolved simultaneously with the constrained equations of motion

Induced Acceleration Analysis

- Kinematic constraints

Point

- no translations

(Allows relative rotation)

$$\rho_x(q) - \rho_{x,o} = 0$$
$$\rho_y(q) = 0$$
$$\rho_z(q) - \rho_{z,o} = 0$$

Weld

- no translations
- no rotations

$$\rho_x(q) - \rho_{x,o} = 0$$
$$\rho_y(q) = 0$$
$$\rho_z(q) - \rho_{z,o} = 0$$
$$\theta_x(q) - \theta_{x,o} = 0$$
$$\theta_y(q) - \theta_{y,o} = 0$$
$$\theta_z(q) - \theta_{z,o} = 0$$

Roll

- non-penetrating
- fore-aft no-slip
- med/lat no-slip
- vertical no-twist

$$\rho_y(q) = 0$$
$$\dot{\rho}_x(q,\dot{q}) = 0$$
$$\dot{\rho}_z(q,\dot{q}) = 0$$
$$\omega_y(q,\dot{q}) = 0$$

Pure rolling

constraint on a rolling body in contact with a plane defined on another body (Hamner et al., 2010)

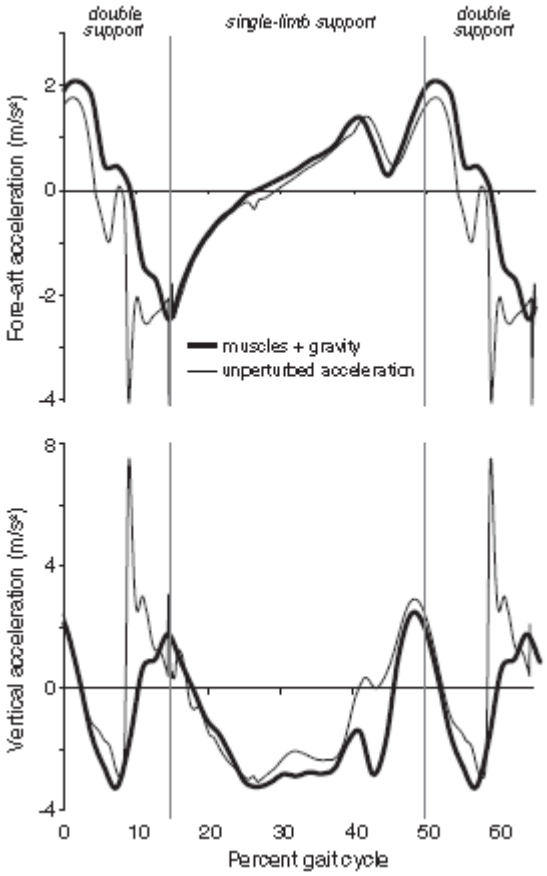
Induced Acceleration Analysis

- Muscle Potentials: accounts for a theoreticcal force increase (1N).
- Muscle IAA: accounts for the instantaneous muscle force(xN)

Induced Acceleration Analysis

- Verify superposition

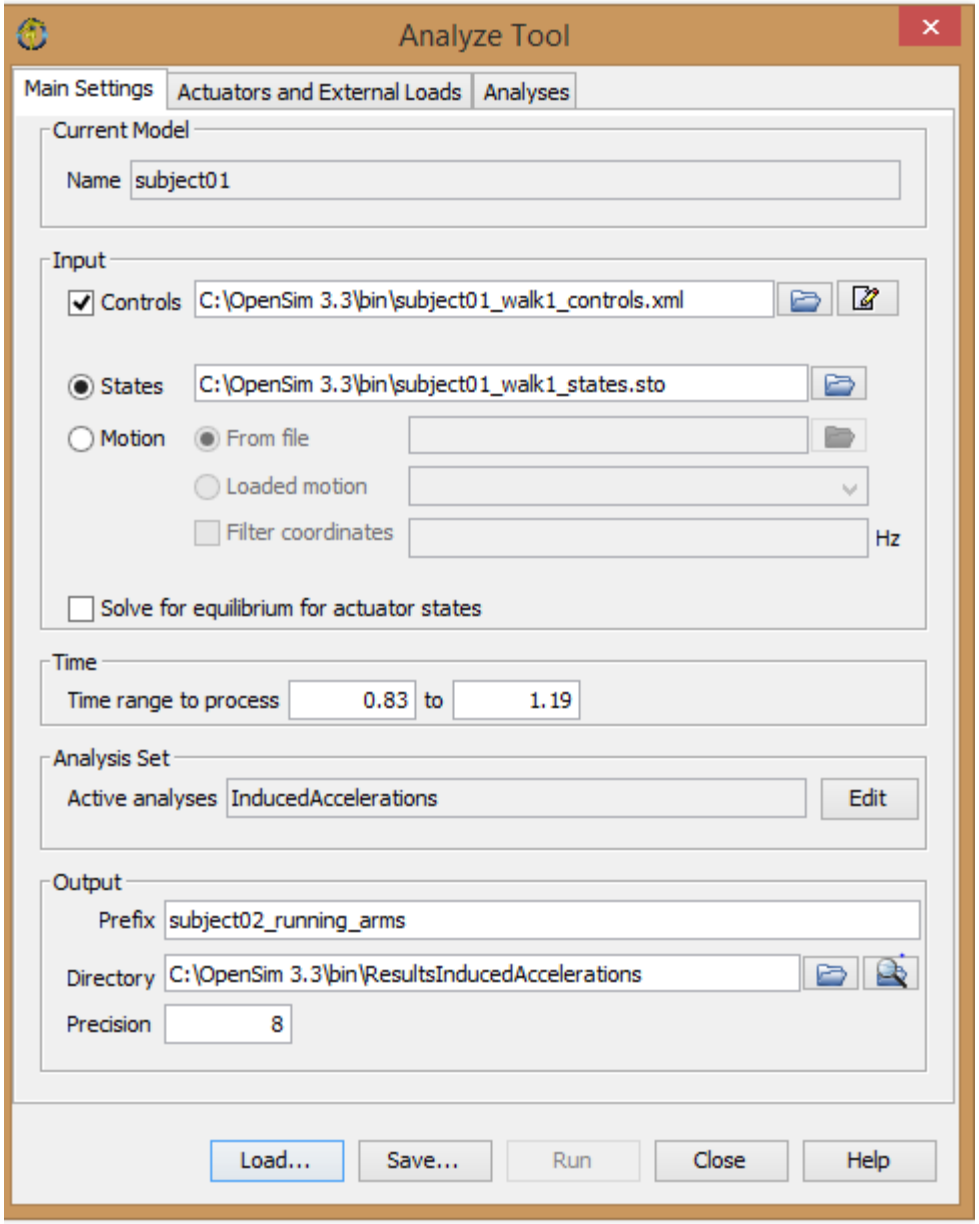
Contribution to com acceleration (Liu, 2006)

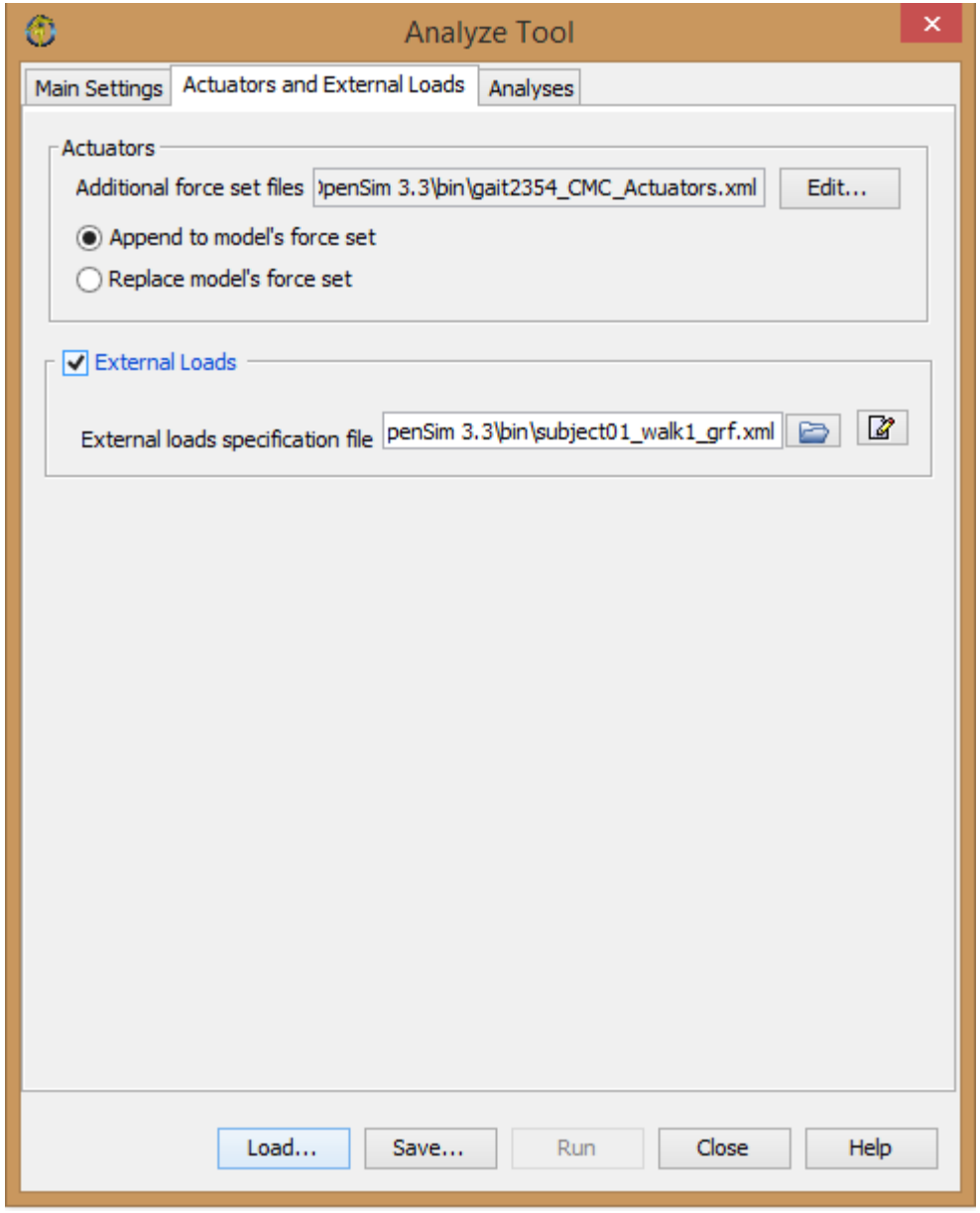


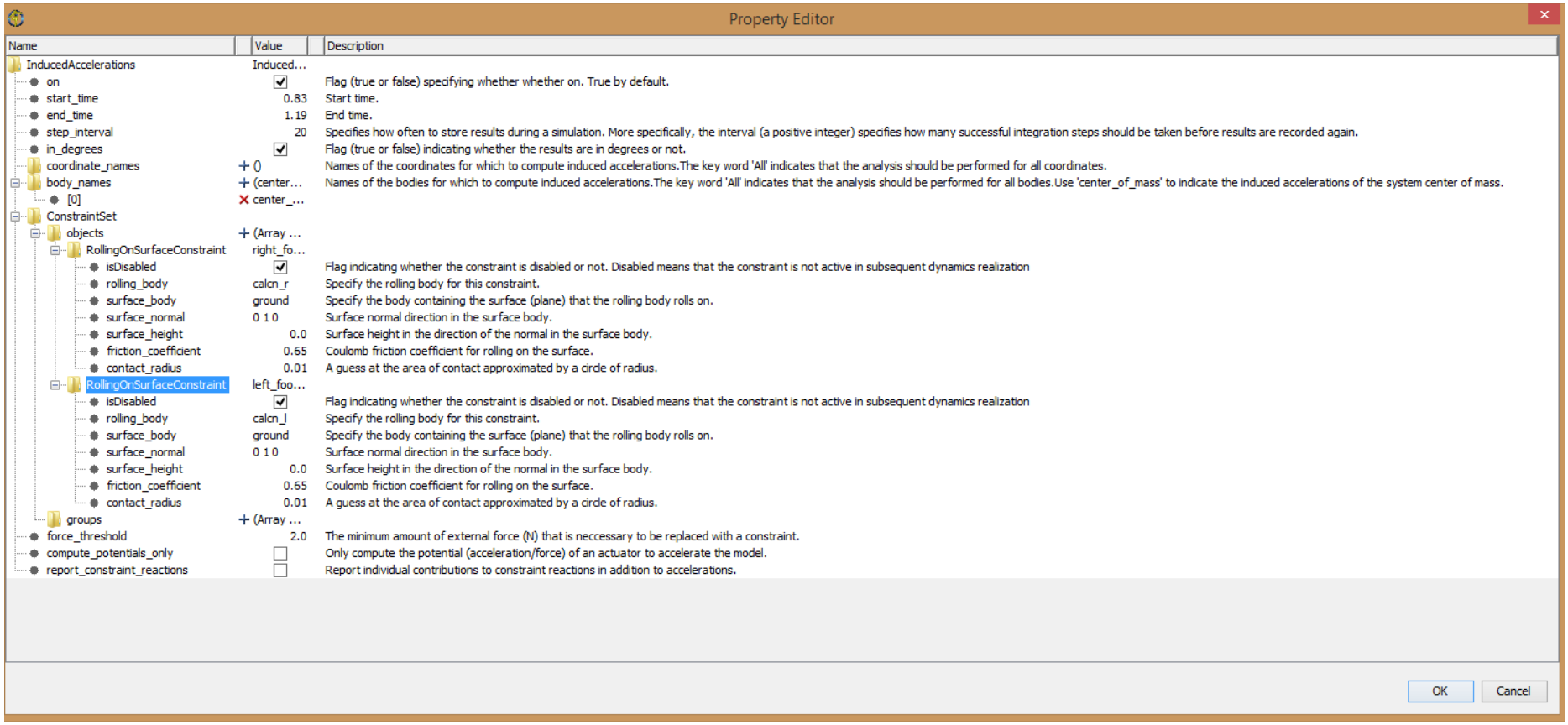
Kinematic
or
Bodykinematic
Analysis

Induced Acceleration Analysis

- How to use IAA:
  - Requires Muscle force distribution (e.g. SO)
  - Does not work in case of missing contact forces (e.g. unilateral forces during double stance)


Analyze Tool
Main Settings
Actuators and External Loads
Analyses
Current Model
Name
subject01
Input
Controls
C:\OpenSim 3.3\bin\subject01_walk1_controls.xml
States
C:\OpenSim 3.3\bin\subject01_walk1_states.sto
Motion
From file
Loaded motion
Filter coordinates
Hz
Solve for equilibrium for actuator states
Time
Time range to process
0.83
to
1.19
Analysis Set
Active analyses
InducedAccelerations
Edit
Output
Prefix
subject02_running_arms
Directory
C:\OpenSim 3.3\bin\ResultsInducedAccelerations
Precision
8
Load...
Save...
Run
Close
Help


Analyze Tool
Main Settings
Actuators and External Loads
Analyses
Actuators
Additional force set files
penSim 3.3\bin\gait2354_CMC_Actuators.xml
Edit...
Append to model's force set
Replace model's force set
External Loads
External loads specification file
penSim 3.3\bin\subject01_walk1_grf.xml
Load...
Save...
Run
Close
Help


Property Editor
Name
Value
Description
InducedAccelerations
Induced...
on
Flag (true or false) specifying whether whether on. True by default.
start_time
0.83
Start time.
end_time
1.19
End time.
step_interval
20
Specifies how often to store results during a simulation. More specifically, the interval (a positive integer) specifies how many successful integration steps should be taken before results are recorded again.
in_degrees
Flag (true or false) indicating whether the results are in degrees or not.
coordinate_names
()
Names of the coordinates for which to compute induced accelerations.The key word 'All' indicates that the analysis should be performed for all coordinates.
body_names
(center...
Names of the bodies for which to compute induced accelerations.The key word 'All' indicates that the analysis should be performed for all bodies.Use 'center_of_mass' to indicate the induced accelerations of the system center of mass.
[0]
center_...
ConstraintSet
objects
(Array ...
RollingOnSurfaceConstraint
right_fo...
isDisabled
Flag indicating whether the constraint is disabled or not. Disabled means that the constraint is not active in subsequent dynamics realization
rolling_body
calcn_r
Specify the rolling body for this constraint.
surface_body
ground
Specify the body containing the surface (plane) that the rolling body rolls on.
surface_normal
0 1 0
Surface normal direction in the surface body.
surface_height
0.0
Surface height in the direction of the normal in the surface body.
friction_coefficient
0.65
Coulomb friction coefficient for rolling on the surface.
contact_radius
0.01
A guess at the area of contact approximated by a circle of radius.
RollingOnSurfaceConstraint
left_foo...
isDisabled
Flag indicating whether the constraint is disabled or not. Disabled means that the constraint is not active in subsequent dynamics realization
rolling_body
calcn_l
Specify the rolling body for this constraint.
surface_body
ground
Specify the body containing the surface (plane) that the rolling body rolls on.
surface_normal
0 1 0
Surface normal direction in the surface body.
surface_height
0.0
Surface height in the direction of the normal in the surface body.
friction_coefficient
0.65
Coulomb friction coefficient for rolling on the surface.
contact_radius
0.01
A guess at the area of contact approximated by a circle of radius.
groups
(Array ...
force_threshold
2.0
The minimum amount of external force (N) that is neccessary to be replaced with a constraint.
compute_potentials_only
Only compute the potential (acceleration/force) of an actuator to accelerate the model.
report_constraint_reactions
Report individual contributions to constraint reactions in addition to accelerations.
OK
Cancel