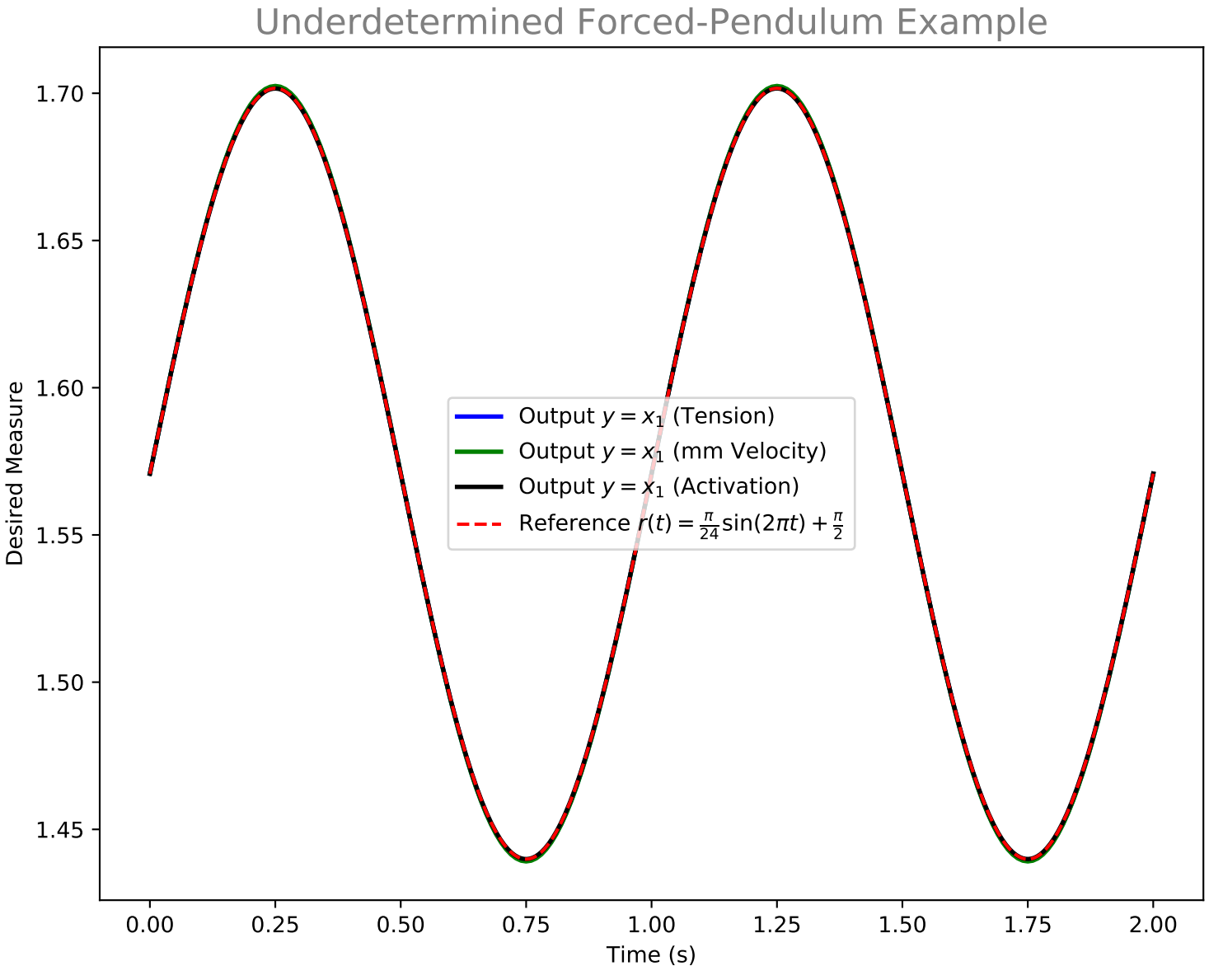
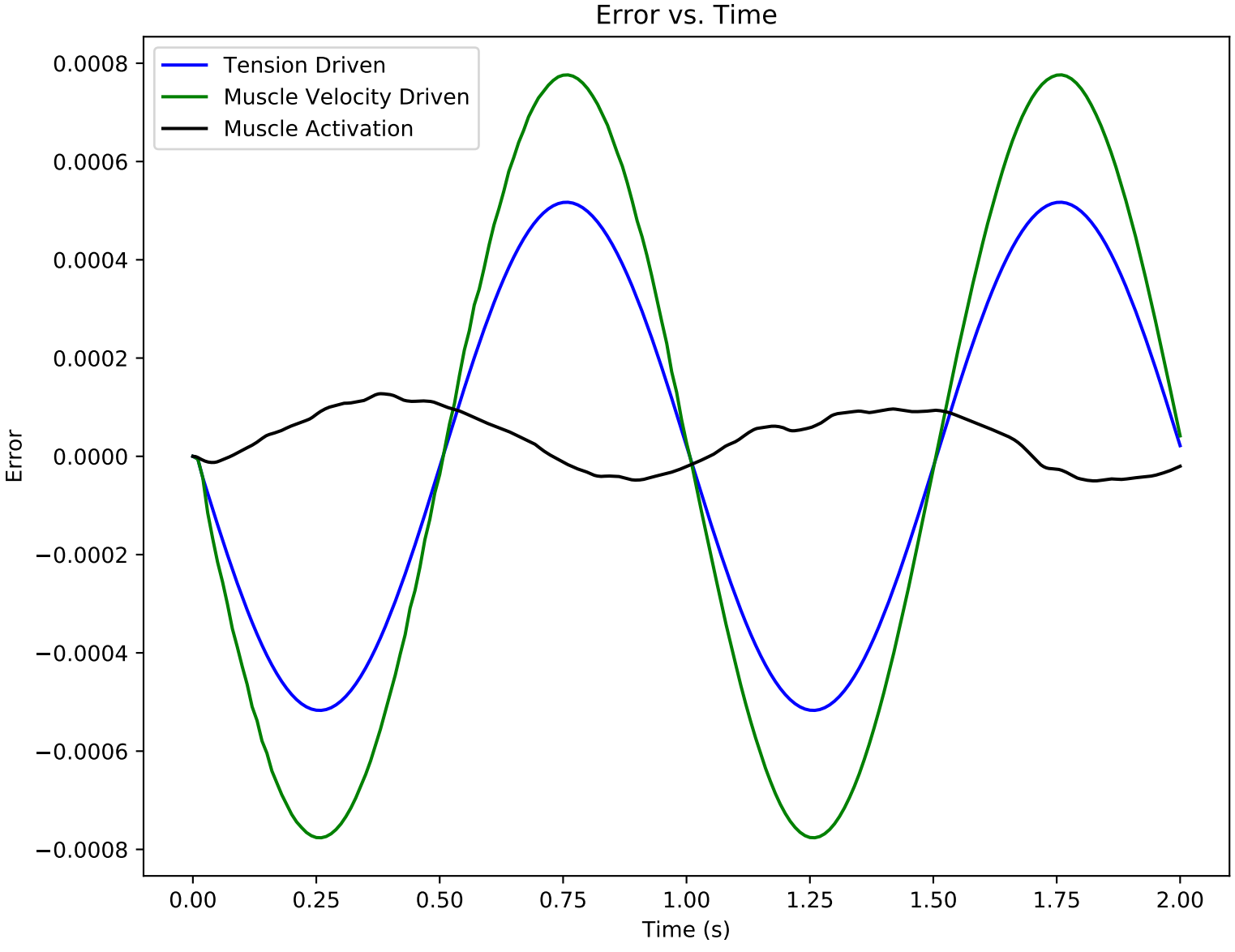
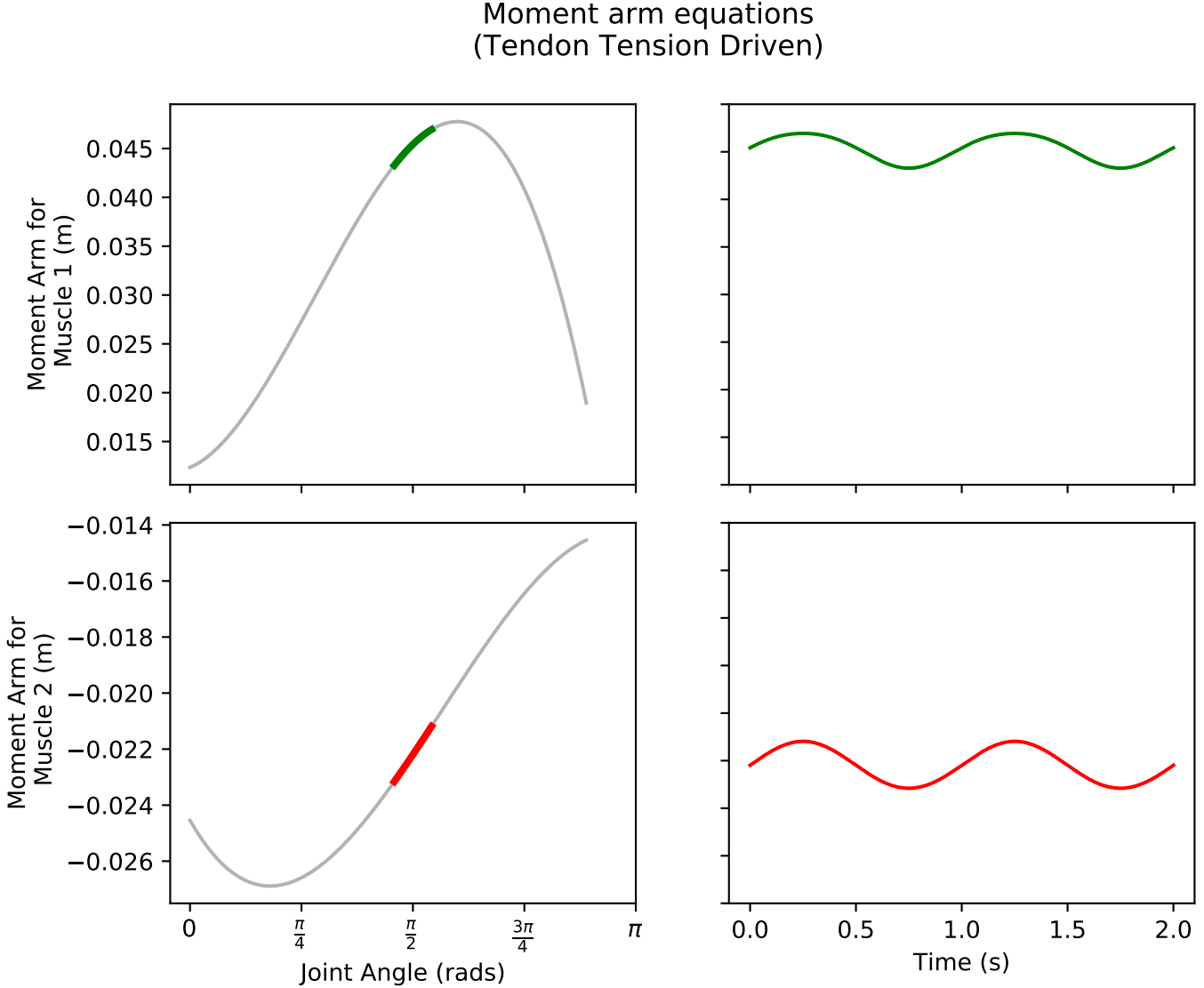
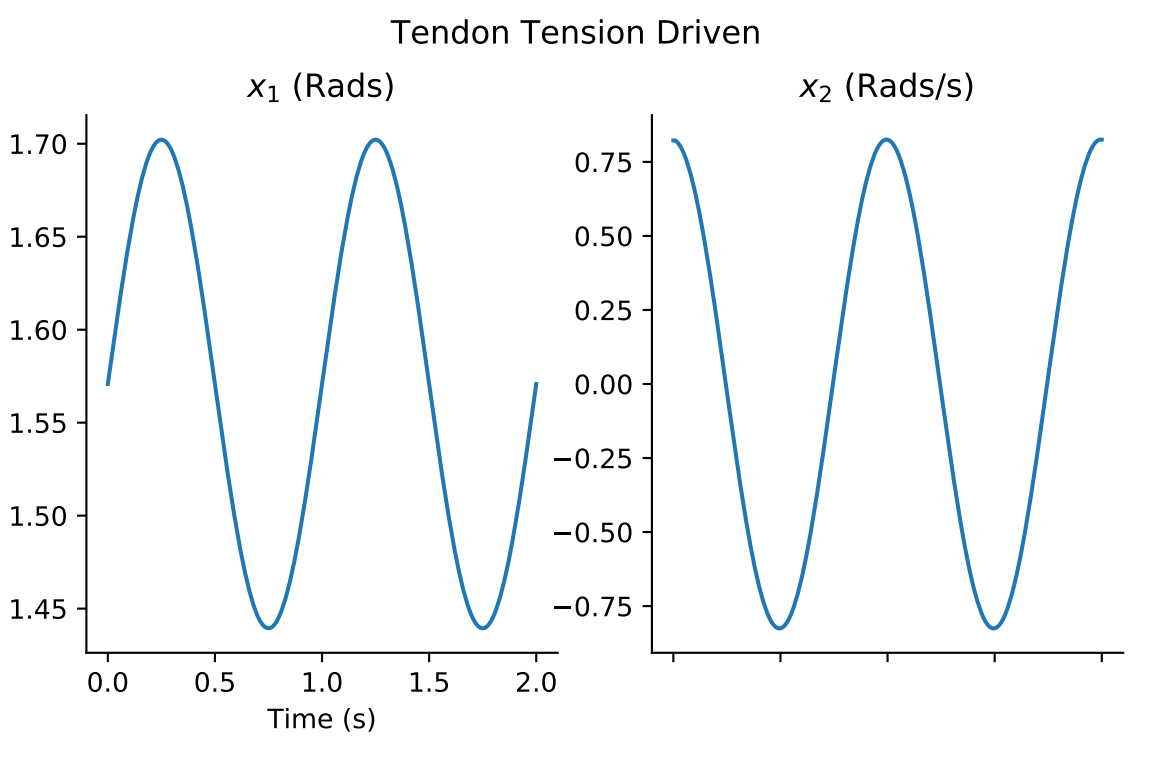
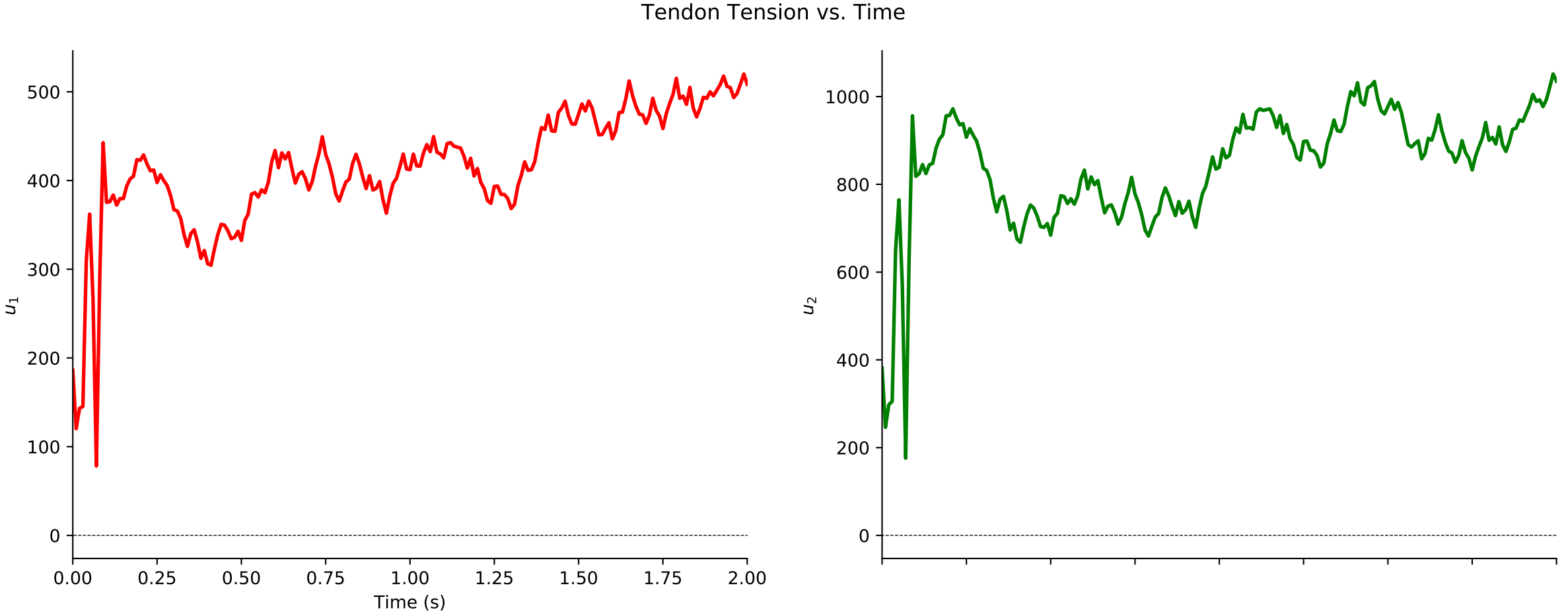
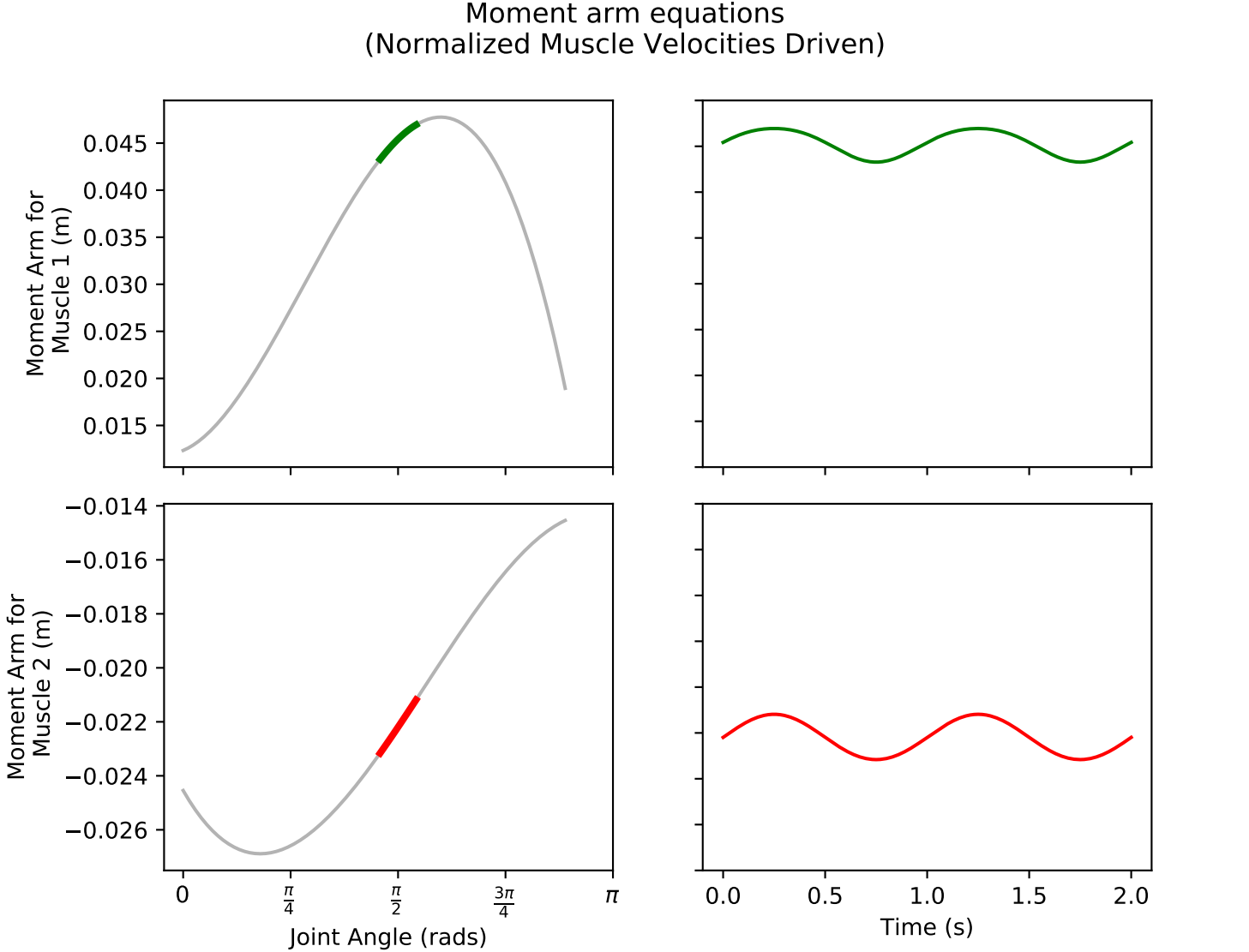

Underdetermined Forced-Pendulum Example
Desired Measure
Time (s)
1.70
1.65
1.60
1.55
1.50
1.45
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Output $y = x_1$ (Tension)
Output $y = x_1$ (mm Velocity)
Output $y = x_1$ (Activation)
Reference $r(t) = \frac{\pi}{24}\sin(2\pi t) + \frac{\pi}{2}$

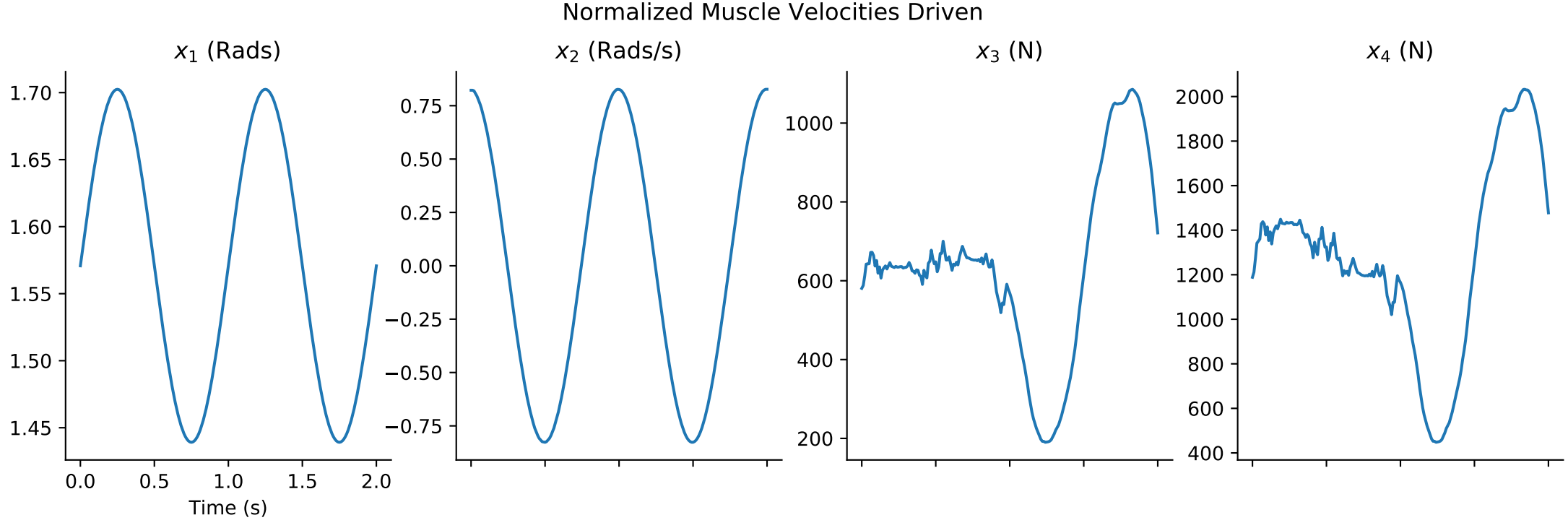

Error vs. Time
Tension Driven
Muscle Velocity Driven
Muscle Activation
0.0008
0.0006
0.0004
0.0002
0.0000
−0.0002
−0.0004
−0.0006
−0.0008
Error
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Time (s)

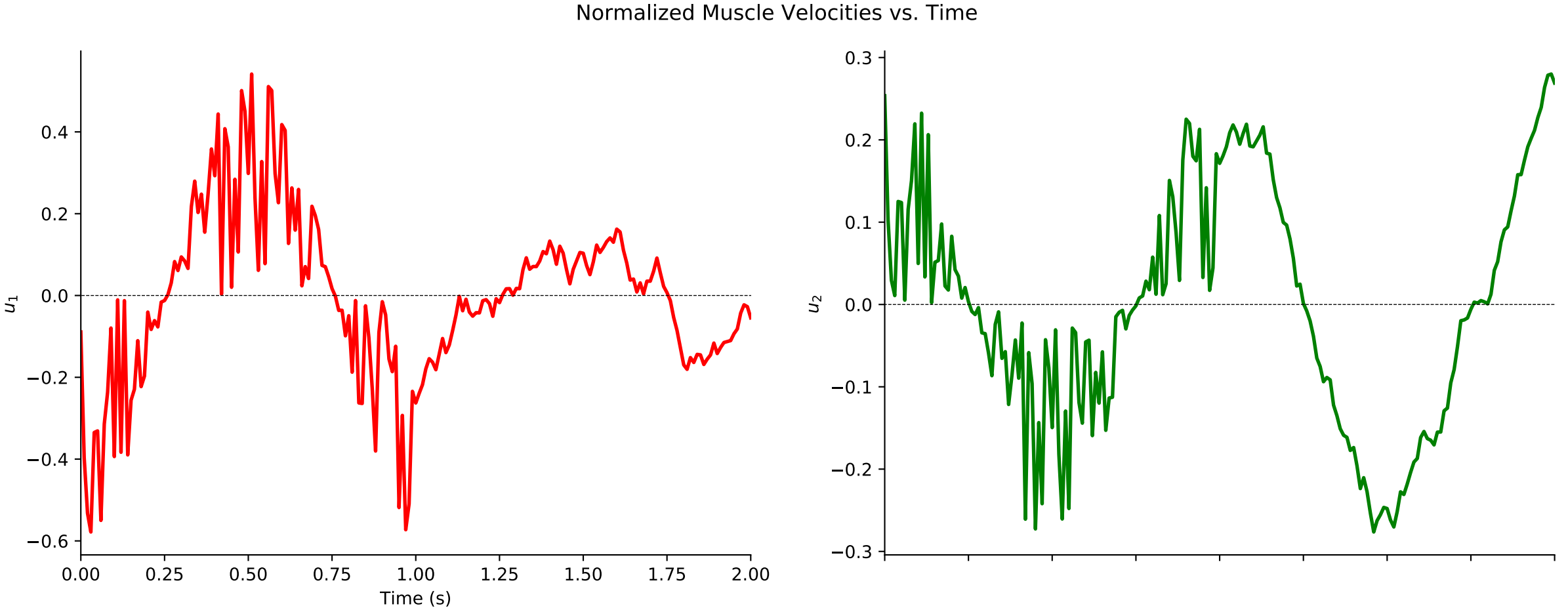

Moment arm equations
(Tendon Tension Driven)
Moment Arm for
Muscle 1 (m)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
Moment Arm for
Muscle 2 (m)
−0.014
−0.016
−0.018
−0.020
−0.022
−0.024
−0.026
0
$\frac{\pi}{4}$
$\frac{\pi}{2}$
$\frac{3\pi}{4}$
π
Joint Angle (rads)
0.0
0.5
1.0
1.5
2.0
Time (s)

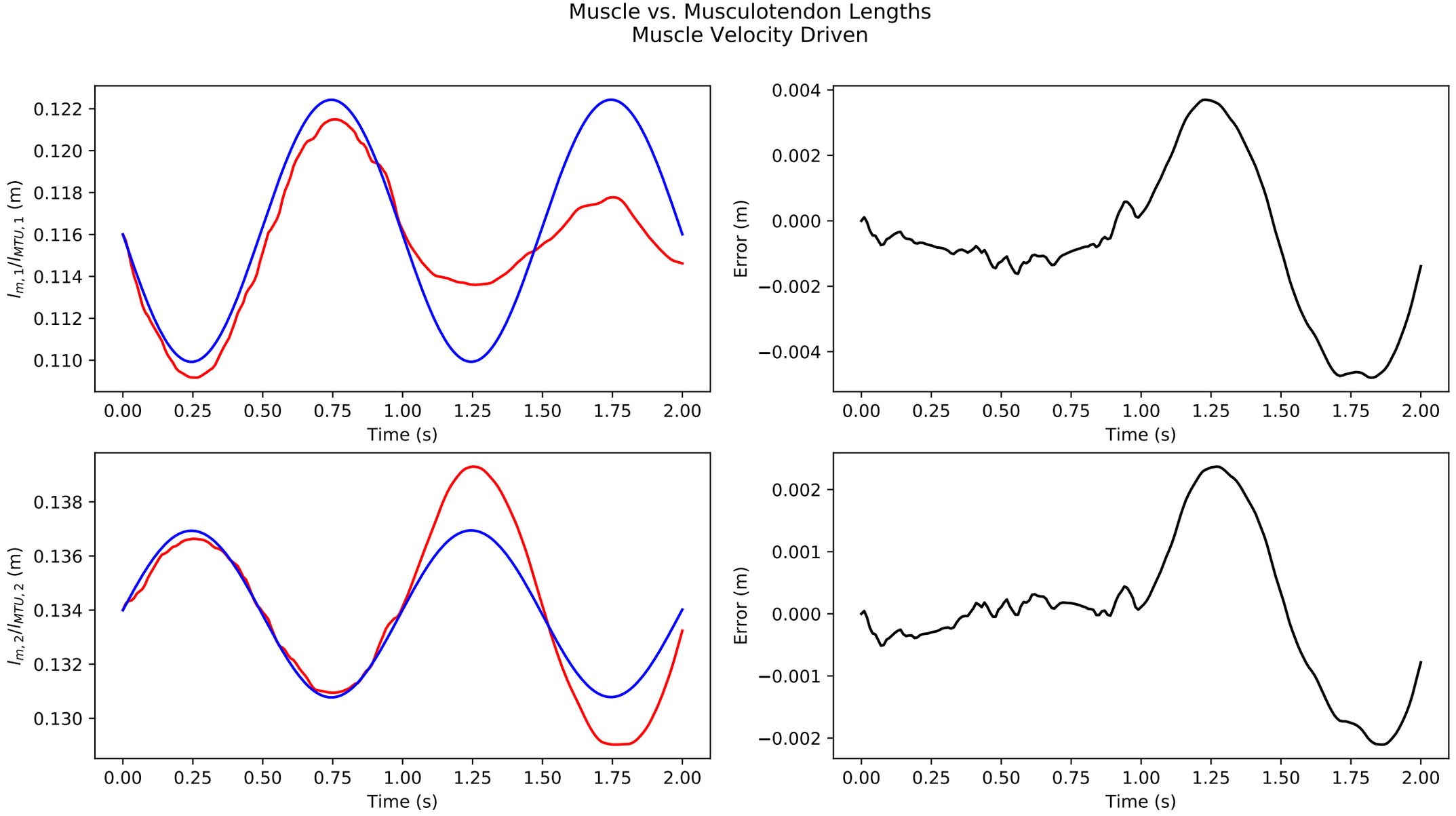

Tendon Tension Driven
x_1 (Rads)
x_2 (Rads/s)
1.70
1.65
1.60
1.55
1.50
1.45
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
0.0
0.5
1.0
1.5
2.0
Time (s)

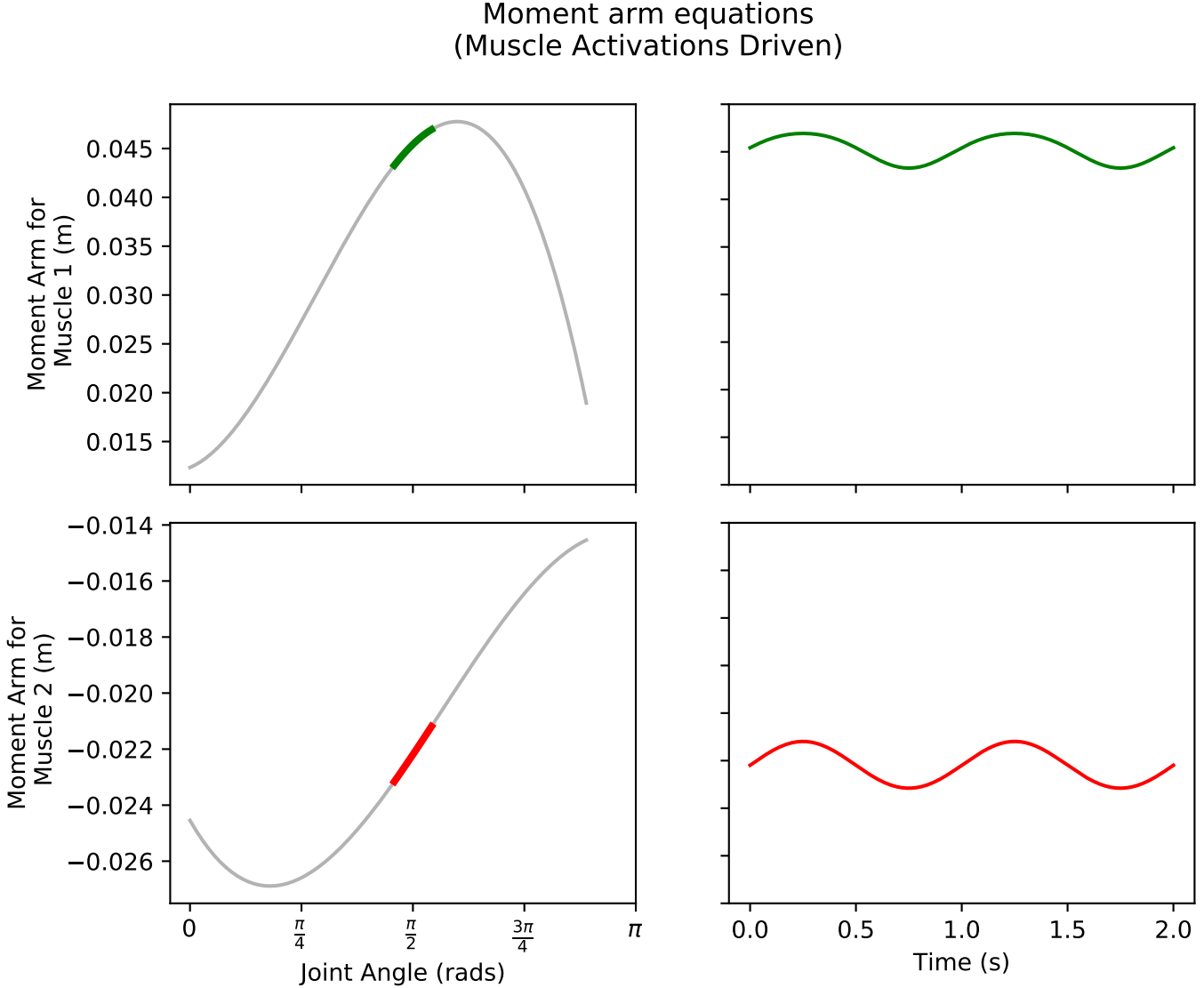

Tendon Tension vs. Time
u_1
500
400
300
200
100
0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Time (s)
u_2
1000
800
600
400
200
0

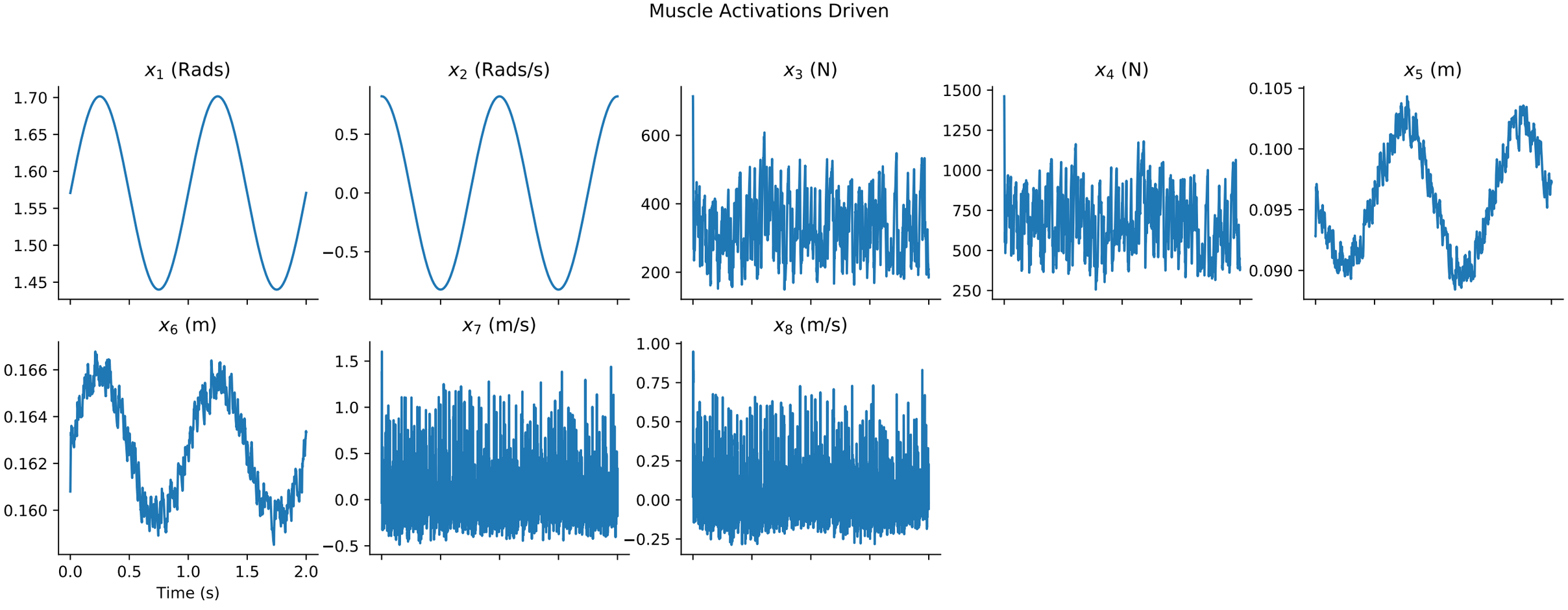

Moment arm equations
(Normalized Muscle Velocities Driven)
Moment Arm for Muscle 1 (m)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
Moment Arm for Muscle 2 (m)
−0.014
−0.016
−0.018
−0.020
−0.022
−0.024
−0.026
0
$\frac{\pi}{4}$
$\frac{\pi}{2}$
$\frac{3\pi}{4}$
π
Joint Angle (rads)
0.0
0.5
1.0
1.5
2.0
Time (s)

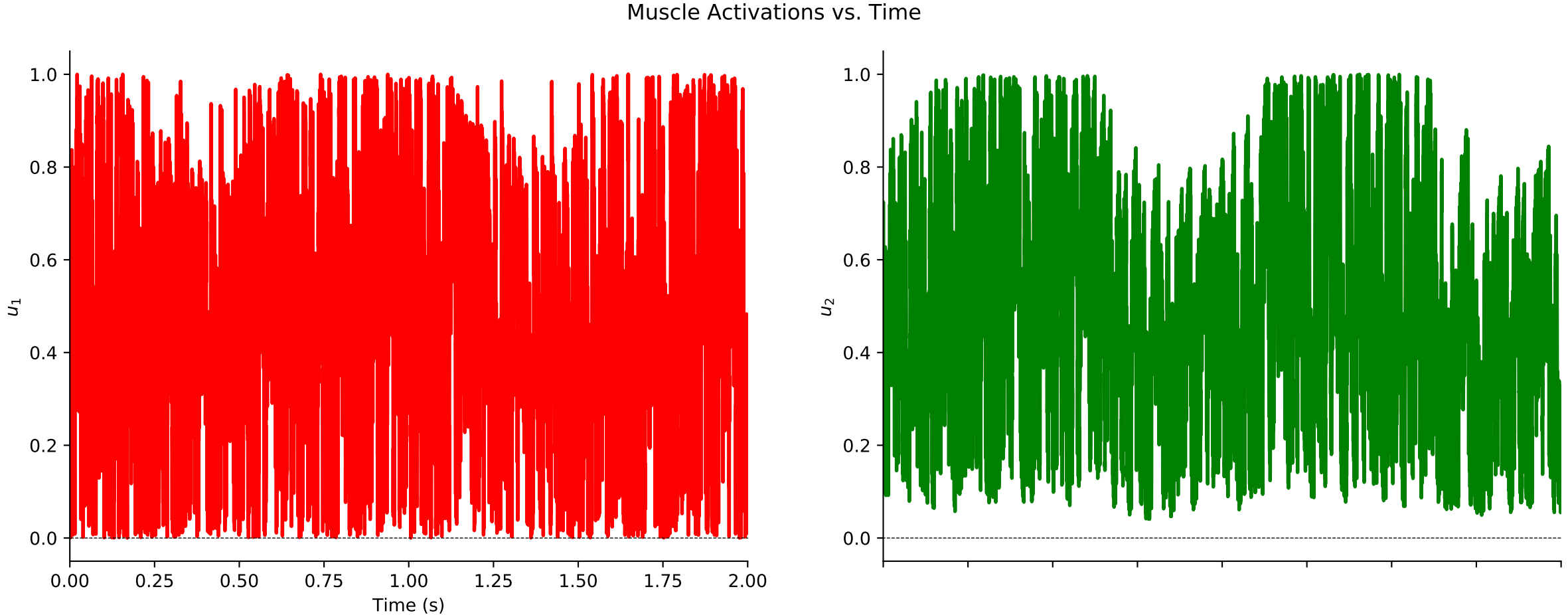

Normalized Muscle Velocities Driven
x_1 (Rads)
x_2 (Rads/s)
x_3 (N)
x_4 (N)
1.70
1.65
1.60
1.55
1.50
1.45
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
1000
800
600
400
200
2000
1800
1600
1400
1200
1000
800
600
400
0.0
0.5
1.0
1.5
2.0
Time (s)

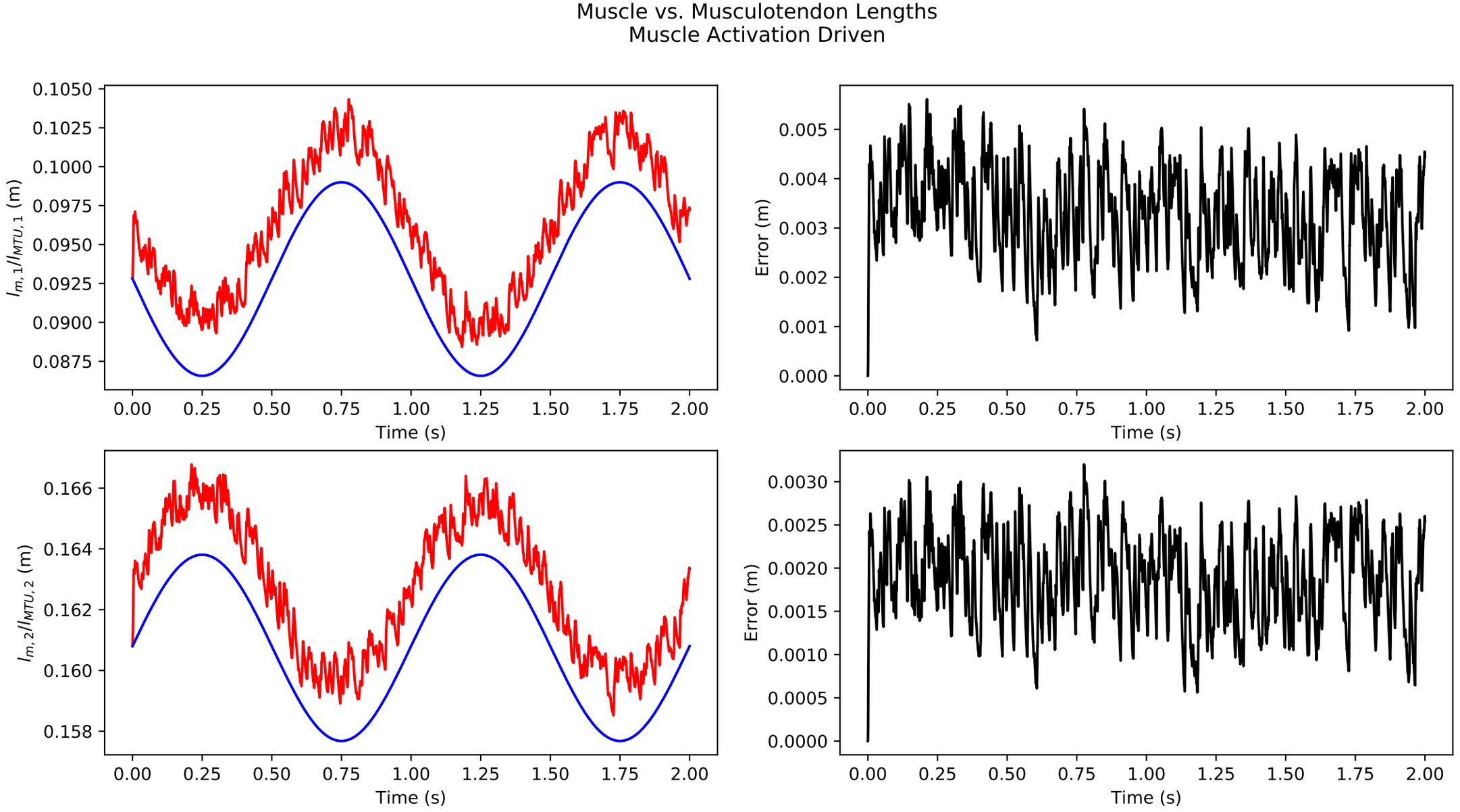

Normalized Muscle Velocities vs. Time
u_1
0.4
0.2
0.0
−0.2
−0.4
−0.6
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Time (s)
u_2
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3


Muscle vs. Musculotendon Lengths
Muscle Velocity Driven
$l_{m,1}/l_{MTU,1}$ (m)
0.122
0.120
0.118
0.116
0.114
0.112
0.110
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Time (s)
Error (m)
0.004
0.002
0.000
−0.002
−0.004
Time (s)
$l_{m,2}/l_{MTU,2}$ (m)
0.138
0.136
0.134
0.132
0.130
Time (s)
Error (m)
0.002
0.001
0.000
−0.001
−0.002
Time (s)


Moment arm equations
(Muscle Activations Driven)
Moment Arm for
Muscle 1 (m)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
Moment Arm for
Muscle 2 (m)
−0.014
−0.016
−0.018
−0.020
−0.022
−0.024
−0.026
0
$\frac{\pi}{4}$
$\frac{\pi}{2}$
$\frac{3\pi}{4}$
π
Joint Angle (rads)
0.0
0.5
1.0
1.5
2.0
Time (s)


Muscle Activations Driven
x_1 (Rads)
x_2 (Rads/s)
x_3 (N)
x_4 (N)
x_5 (m)
x_6 (m)
x_7 (m/s)
x_8 (m/s)
Time (s)


Muscle Activations vs. Time
u_1
u_2
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Time (s)


Muscle vs. Musculotendon Lengths
Muscle Activation Driven
$l_{m,1}/l_{MTU,1}$ (m)
Time (s)
Error (m)
Time (s)
$l_{m,2}/l_{MTU,2}$ (m)
Time (s)
Error (m)
Time (s)