Tendon Reflexes

Suriya Selvarajan (DTP) Varghese Reji (DAA)

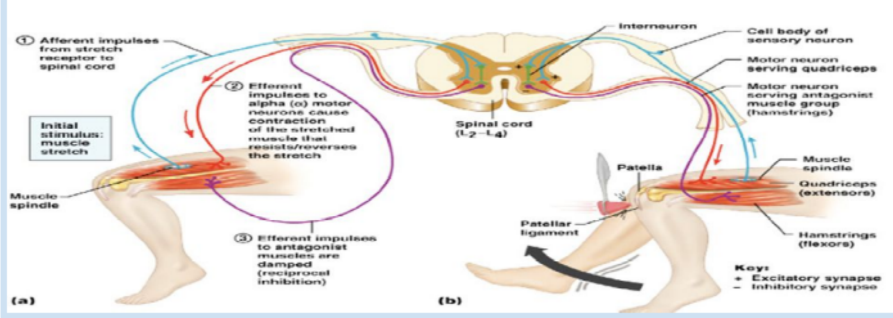
TIFR Mumbai

February 4, 2021

Outline

The deep Tendon Reflex

- If you tap on the tendon of a muscle, it constracts. Its synergista contract and its antagonists are inhibited.-polysynaptic reflex
- A tap on the patellar tendon stretches the extensor muccle and its spindles.



① Afferent impulses from stretch receptor to spinal cord
② Efferent impulses to alpha (α) motor neurons cause contraction of the stretched muscle that resists/reverses the stretch
③ Efferent impulses to antagonist muscles are damped (reciprocal inhibition)
Initial stimulus: muscle stretch
Muscle spindle
(a)
Interneuron
Cell body of sensory neuron
Motor neuron serving quadriceps
Motor neuron serving antagonist muscle group (hamstrings)
Spinal cord (L2–L4)
Patella
Muscle spindle
Quadriceps (extensors)
Patellar ligament
Hamstrings (flexors)
Key:
+ Excitatory synapse
– Inhibitory synapse
(b)

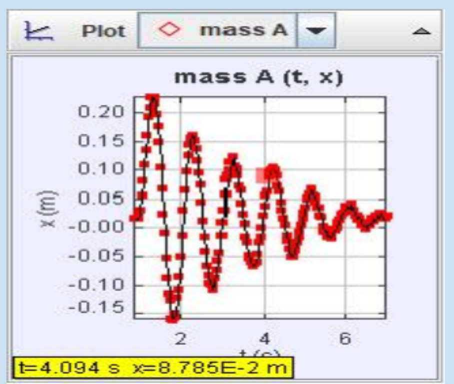
Materials Required

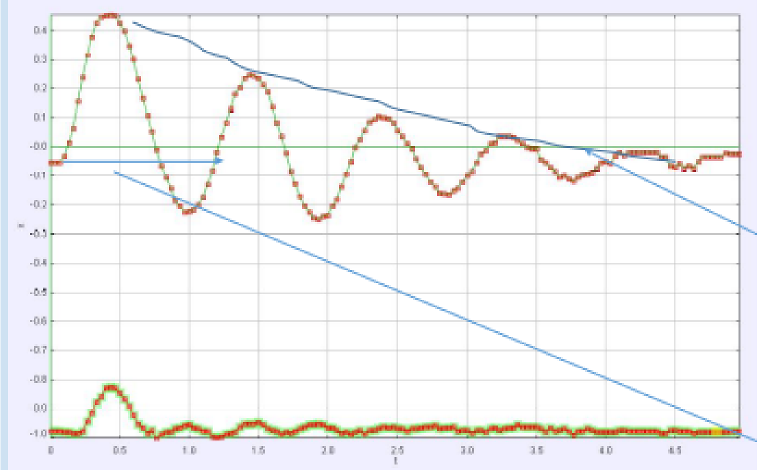
- Person with an intact knee
- Knee Hammer
- Video from the side which measures theta change with time

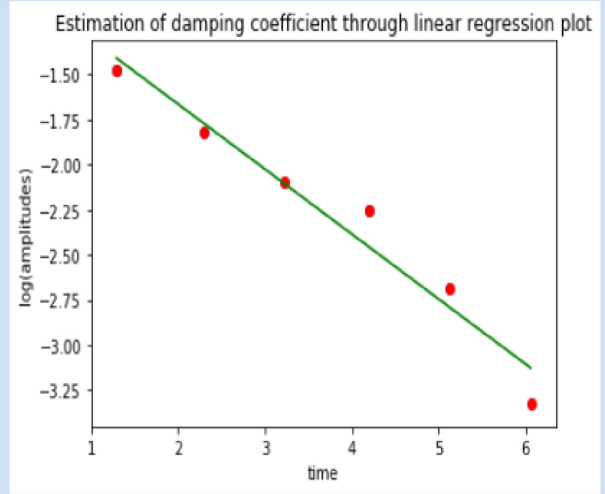
Knee Jerk Reflex

- The reflex signal passes back to the quardriceps muscle via the alpha motor neuron to produce a sudden contraction and forces the leg to move forward with a jerk.
- As the muscle relaxes, the leg system acts as a **Damped Compound Pendulum**, swinging back and forth for a few oscillations.
- Eventually the leg returns to the normal position.
- Forward movement corresponds to contraction of tendon
- backward motion corresponds to stretch of tendon

Tracker output




0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
0.0
-1.0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
t


Estimation of damping coefficient through linear regression plot
log(amplitudes)
−1.50
−1.75
−2.00
−2.25
−2.50
−2.75
−3.00
−3.25
1
2
3
4
5
6
time

Model

Assumptions:

- Small oscillations: $\sin\theta \sim \theta \qquad \theta \sim \frac{x}{L}$
- Knee modelled to be a rod of uniform mass density
- No voluntary effort
- Mass: 3.5kg, L=0.5m, $I = \frac{ML^2}{3}$
- Underdamped Oscillator: EOM:

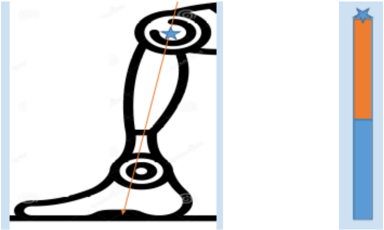
$$\ddot{\theta} = -\frac{b}{I}\dot{\theta} - \frac{mgl\lambda}{I}\theta$$

$$x(t) = e^{-\frac{bt}{2I}}\cos(\omega' t + \phi) \qquad \frac{b}{2I} = \sigma$$

$$\omega' = \sqrt{\frac{mgl}{2I} - \frac{b^2}{4I^2}} \qquad \omega^2 = \frac{mgl}{2I}$$

Moment of Inertia

For θ change using moment of inertia



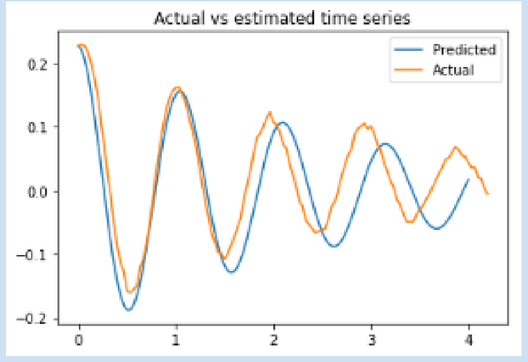
Moment of Inertia for the possible models

$$\ddot{\theta} = -\frac{b}{I}\dot{\theta} - \frac{mgl\lambda}{I}\theta$$

	Predicted moment of inertia (kg m^2)	Computed moment inertia	Lambda
	0.775	0.3	1/2
	0.32	0.4	5/12
	0.904	0.146	7/12

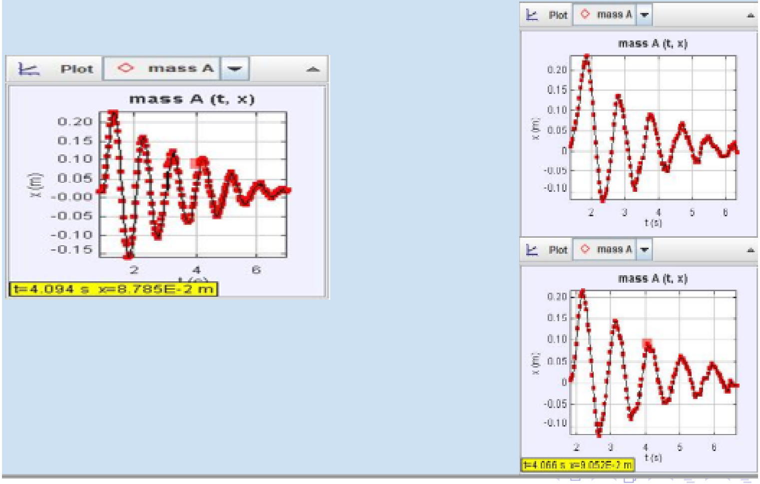
Prediction:1

$$x(t) = Ae^{-\sigma t}\cos(\omega t + \phi)$$

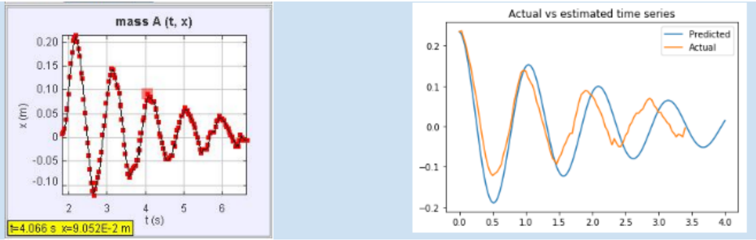


T=1.9s, $\sigma = 0.36/s$

Abrration:

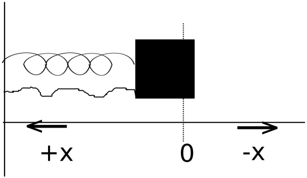

Plot
mass A
mass A (t, x)
0.20
0.15
0.10
0.05
-0.00
-0.05
-0.10
-0.15
x (m)
2
4
6
t=4.094 s x=8.785E-2 m
Plot
mass A
mass A (t, x)
0.20
0.15
0.10
0.05
0
-0.05
-0.10
x (m)
2
3
4
5
6
t (s)
Plot
mass A
mass A (t, x)
0.20
0.15
0.10
0.05
0
-0.05
-0.10
x (m)
2
3
4
5
6
t (s)

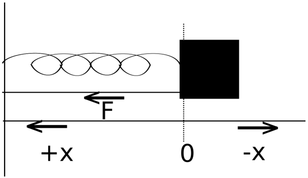
Prediction 2:



$\sigma = 0.41s \qquad T = 1.9s$

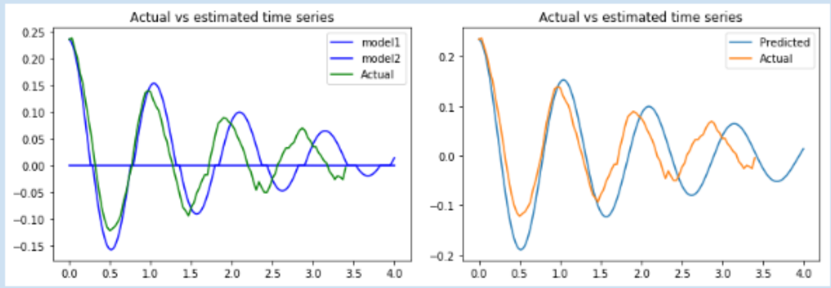
Modified Model





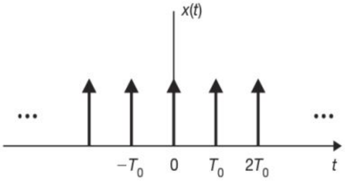
$$x(t) = \begin{cases} Ae^{-\sigma t}\cos(\omega t + \phi) & \text{for } x > 0 \\ Ae^{-\sigma t}\cos(\omega t + \phi) + \frac{F}{k} & \text{for } x > 0 \end{cases}$$

Results Modified Model(Parameter F=0.15)



For future work

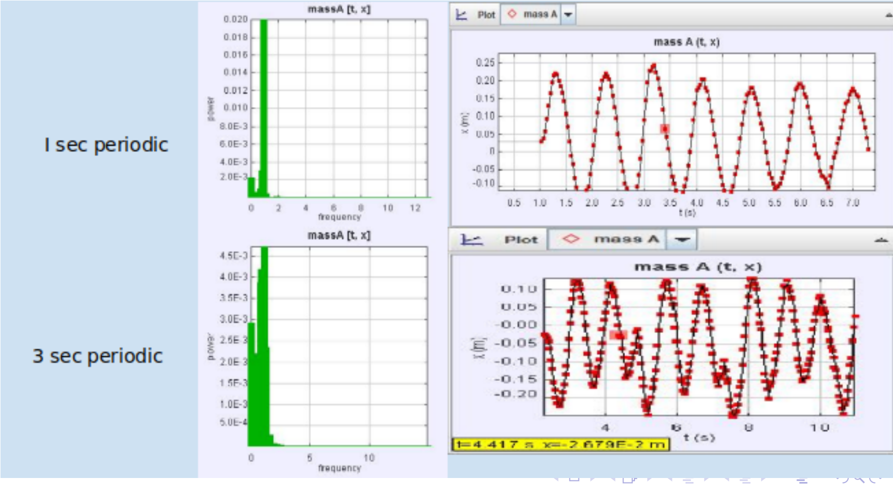
- It takes about 6s for complete return to equilibrium position
- Train of impulse response? Time interval 3s and 1s and see if the system response is a linear sum or not.



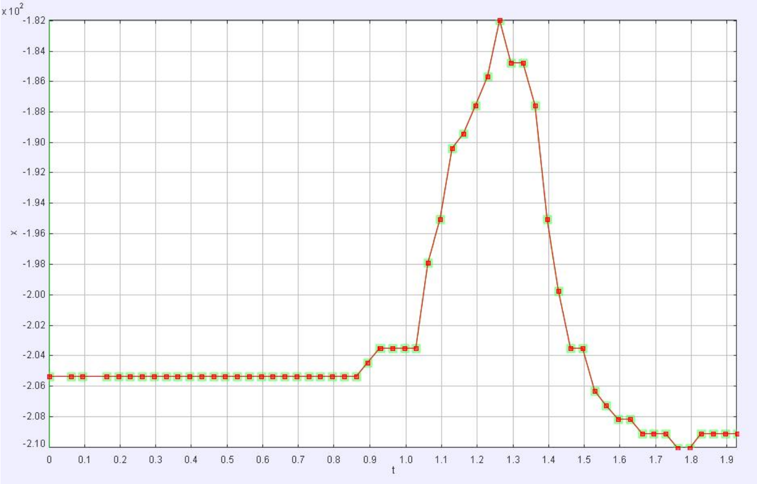
$\delta_{T0}(t) = \sum_{k=-\infty}^{k=\infty} \delta\left(t - kT_0\right)$

$\Rightarrow$Sum of Impulse Response

Driving Signal



Voluntary Stop:Reaction Time



References

- A modified dynamic modef of the human lower limb during complete gait cycle S M Nacy1*, S S Hassan1 and M Y Hanna1
- Nonlinear complexity of human biodynamics engine Vladimir G. Ivancevic
- Lagrangian Approach to Modeling the Biodynamics of the Upper Extremity: Applications to Collegiate Baseball Pitching
- H. Hong, S. Kim, C. Kim, S. Lee, and S. Park, "Spring-like gait mechanics observed during walking in both young and older adults," Journal of biomechanics, vol. 46, pp. 77-82, 2013.
- Stanley Dunn, Alkis Constantinides, Prabhas V. Moghe - Numerical Methods in Biomedical Engineering (2005)
- Mechanical properties of human patellar tendon at the hierarchical levels of tendon and fibril