Tendon Reflex

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Chapter 1

Introduction

Deep tendon reflexes demonstrate the homeo-stasis between the cerebral cortex and the spinal cord. When these reflexes are disrupted, hyperreflexia (disease induced increased reflexes) or hyporeflexia/areflexia(decreased reflexes) occurs. Clinically,almost every time a clinician performs a physical examination on a patient, he or she elicits multiple stretch reflexes. The purpose is to determine how much background excitation, or “tone,” the brain is sending to the spinal cord. This reflex is elicited as follows. Knee Jerk and Other Muscle Jerks Can Be Used to Assess Sensitivity of Stretch Reflexes. Clinically, a method used to determine the sensitivity of the stretch reflexes is to elicit the knee jerk and other muscle jerks. The knee jerk can be elicited by simply striking the patellar tendon with a reflex hammer; this instantaneously stretches the quadriceps muscle and excites a dynamic stretch reflex that causes the lower leg to “jerk” forward. The reflex signal passes back to the quadriceps 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 and backward motion corresponds to stretch of tendon. This motivates us to view the oscillation of the leg as a damped pendulum.

Chapter 2

Experimental Setup

2.1 Materials Required

- Person with an intact knee
- Knee hammer
- Video from the side which measures θ change with time
- Tracker software
- Tracking tape
- Laptop for analysis
- Python coding for modelling

2.2 Procedure

The person is make to sit on the tabke high enough so that the leg is freely hanging. The patiant is advised to sit in a relaxed manner and a gentle tap with the knee hammer is given just below the knee. The entire process was recording using a video recorder from the mobile. The recorded videos are then transferred to the tracker software. The videos are taken under different conitions namely:

- Single tap with no voluntary effort
- Multiple periodic taps
- Single tap with voluntary control

Measurements

- Tθ as a function of time

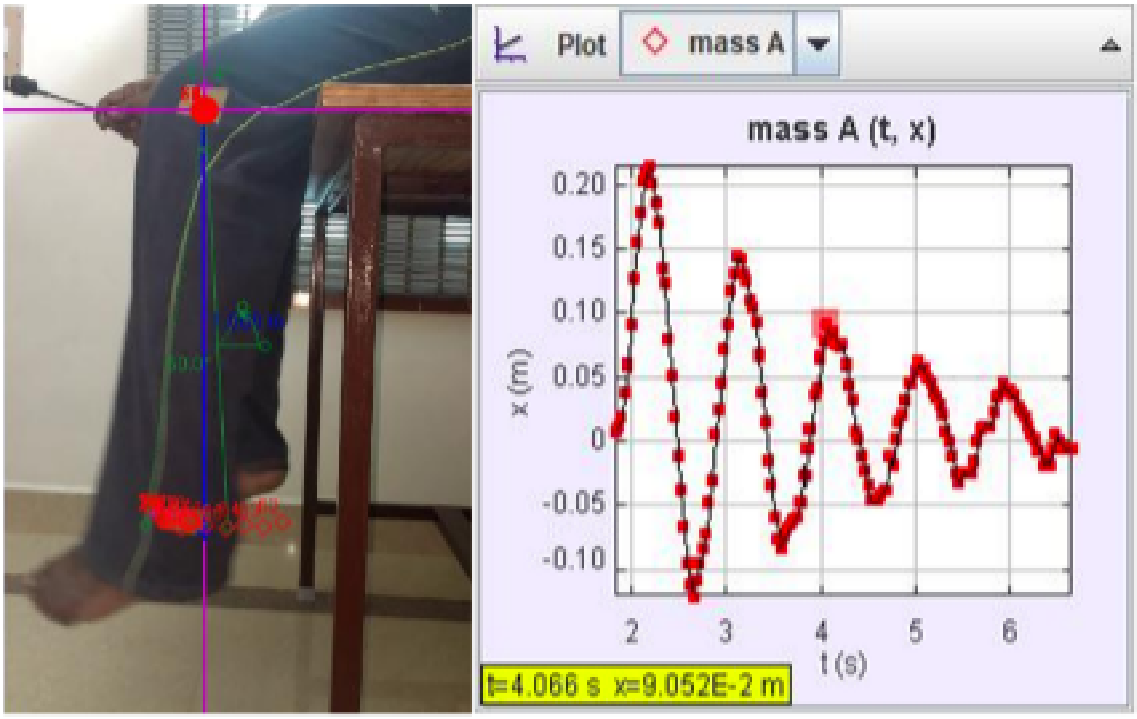


Figure 2.1: A snapshot from tracker analysis and output of the measurements which seemly suggests the behaviour is that of a damped oscillator. The two trcking points are that of the knee which is one fixed at the knee and other at the ankle which freely moves.

- Length of the led idealized as a uniform mass density of the rod of length $0.5m$ (hence assume the center of mass at the center)
- Mass estimated to be 5% of the total body mass(3.5kg)

Chapter 3

Modelling, assumptions and observations

Based om the small θ oscillations assumotion ($\sin\theta \approx \theta \approx \frac{x}{L}$) the model of that of a damoed oscillator was used. The measurements were used to estimate the decaying coefficient and also the time period of oscillations were estimated from the measurements which can be used to obtain the ω' of the oscillation.

The working formulas are

$$\ddot{\theta} = -\frac{b}{I}\dot{\theta} - \frac{mgl}{2I}\theta + voluntary \tag{3.1}$$

$$x(t) = e^{\frac{-bt}{2I}} \cos\omega' t \tag{3.2}$$

$$\omega' = \sqrt{\frac{mgl}{2I} - \frac{b^2}{4I^2}} \tag{3.3}$$

$$\omega^2 = \frac{mgl}{2I} \qquad \frac{b}{2I} = \sigma$$

We can estimate σ and ω' from the measurements.

3.1 Observation and results

We used linear regression to estimate to estimate the value of σ

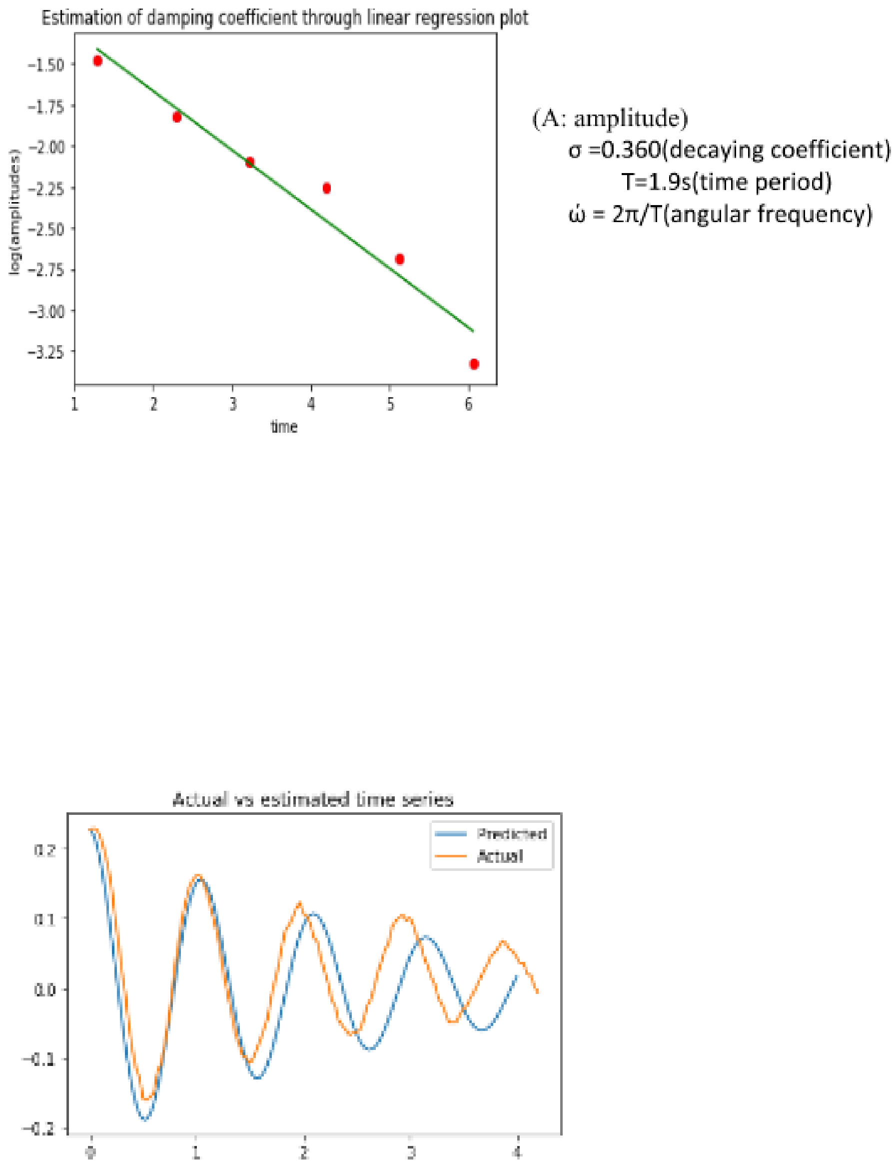
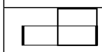
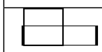


Figure 3.1: The model predicted qualitatively follows the measurements. Generated by python code

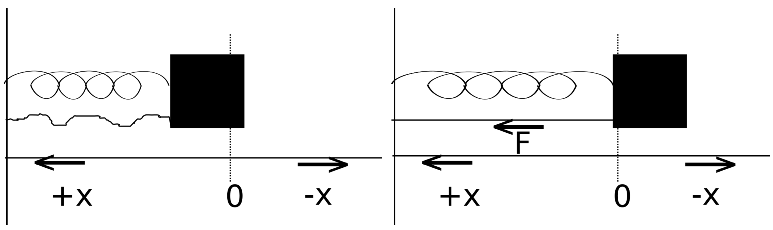
Table 3.1: Fro three different assumptions. (1) Uniform mass density, (2) proximally more dense. (3) Distally more dense/ λ: The ratio of location of the center of mass to the actual length.

Model	Predicted Moment of Inertia(kgm^2)	Computed Moment of Inerita(kgm^2)	λ
	0.775	0.3	$\frac{1}{2}$
	0.32	0.4	$\frac{5}{12}$
	0.904	0.146	$\frac{7}{12}$

The table 3.1 shows the monent of inertial estimated for different assumptions. The assumption with proximal more dense seems to qualitatively match with the estimates moment of inertia of the leg. But need further refinement.

3.2 Model with an oscillator

I search of the better model to explain the behavior that the backward movement of the leg as little less when compare to the forward motivatd us to modify the model as follows.



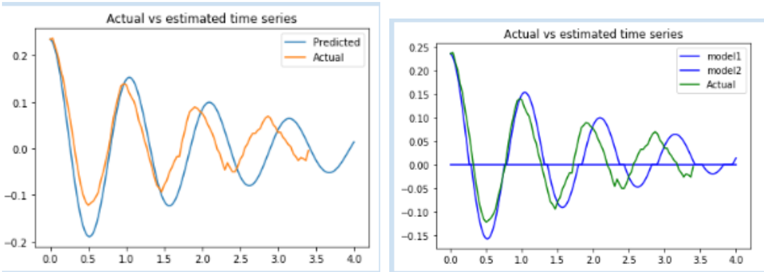
(a) $x < 0$ (b) $x > 0$

Figure 3.2: Model of oscillator

From observtion, we made this model. In the plot, we can see that of the oscillator is at $+x$ region, it oscilates like a normal oscillator. But the oscillator is ar $-x$ region, it is shifted a little bit. It is like a constant force acted on the oscillator. From that we can say that there is a constant force act on the oscillator if it is in negative region and that is not present if it is in positive region. It looks like a string tied with the oscillator. The equation of oscillator will be then

$$x(t) = \begin{cases} Ae^{-\sigma t}\cos(\omega t + \phi) & \text{for} x > 0 \\ Ae^{-\sigma t}\cos(\omega t + \phi) + \frac{F}{k} & \text{for} x < 0 \end{cases} \tag{3.4}$$

The above figute was fit for a parameter $F = 0.15$ which qualitatively fit



(a) Model 1 Prediction (b) Model 2 Prediction

Figure 3.3: Model Plots

the measurements. The amplitude in the backward movement seems to be predicted quite with the model 2 over to model 1.

Chapter 4

Conclusion

We proposed two models one a damped oscillator and a modified damped oscillator model to understand the behaviour of the deep tendon reflexes. Model 2 seems to fit better with the observations.

Future work

It takes about 6s for complete return to equibilirum position with each oscillation taking about 2 seconds. Train impulse response? Time interval 3s and 1s (periodic tapping) and see if the system response is a linear sum or not.

Relevent papers

- A modified dynamic model of the human lower linb during complete gait ccycles-M Nacy1, S S Hassan and M Y Hanna
- 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 https://doi.org/10.1152/japplphysiol.01172.2011