# Scaling code for NeuroNex

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## Overview

This code performs calculations, simulations, and plots of how one-dimensional systems with mass, viscous damping, and elastic and gravitation “spring” forces respond to external forcing. Currently, the code helps answer the following questions:

* How is energy from an actuator converted into the limb’s kinetic and potential energy, and how much is dissipated?
* How is unanticipated energy from perturbations dissipated?

Some preliminary functions in this code also seek to address the question:

* How does delayed feedback stabilize or destabilize the motion of the limb?

## Running the code

The output of the code is primarily figures. To run the whole package, run the “generateAllFigures” script. It sets some basic parameter values and then passes them to various functions, which generate specific figures. These are outlined below.

## Most relevant code

### Functions

* NEURONEXscalingPlot
  + Plots figures 1 and 2 from our funded NeuroNex proposal, the “T and L” plot. Our understanding of the system has evolved since this plot was generated. However, this script has been kept up to date.
* scalingInverseDynamicsAcrossScales
  + Plots inverse dynamics calculations of inertial, viscous, and spring forces in response to a dictated motion form (sinusoidal, “sine rise”, erf rise, exponential rise, and exponential wave). Multiple plots are plotted together on a “T and L” plot. This figure can be a bit messy, but it is useful for building intuition for how T and L affect which forces are present.
* phiAndX
  + Plots figures for our in-preparation contribution for Science. This includes “T and L” plots, color coded by forcing regime; additional work-loop and perturbation plots; and the scaling of animal behaviors.
* phiGeneratesResponse
  + Plots figures demonstrating how phi, the phase lag of limb motion behind the actuator force, predicts different muscle activation patterns observed in one-off behaviors. This includes, for example, the triphasic muscle activation pattern observed in human arm motions.
* simulateJointReponse
  + Plots limb motion and forces given k, c, m, s (muscle lever arm fraction), L, T, and a simulation duration.

### Scripts

* zetaAcrossScales
  + Approximates a baseline damping value (i.e. damping when L=1) using the scaling of m and k and experimental studies of joint damping across scale. This script also plots how the spring forces from elastic components and gravity scale relative to one another.

## Not immediately relevant code

There is a fair amount of code in this folder related to how feedback delays scale and the impact of feedback delays on limb stability. This work is ongoing. However, here are some functions present in the folder.

### Functions

* scalingDelaysPlot
  + Plots data on how neuromuscular delays depend on L and T.
* limbResponseWithFeedbackScanGain
  + Plots boundaries and limits on feedback gain as a function of dynamics and feedback delay.
* simDelayedDamping
  + Convenience wrapper function for simulating a system of delayed differential equations (i.e. dynamics with delayed feedback)
* delayedFBEOM
  + Equation of motion for a system with delayed feedback
* findRootsDelayedFeedback
  + Numerically calculates the roots of the characteristic equation of a system with delayed feedback.