Homework 7 Solutions

1. Neuromuscular System

(a) Components

See notes.

(b) Pathologies

Some possibilities:

- fibrous dysplasia – effects bone
- osteoarthritis – effects joints
- EhlersDanlos syndrome – effects connective tissues (ligaments, tendons)
- muscular dystrophy – effects muscles
- amyotrophic lateral sclerosis (ALS) – effects motor neurons
- diabetic neuropathy – effects neural connections to sensory receptors

2. Muscle Contractions

Examples:

- isometric $\rightarrow$ push against a wall
- isotonic $\rightarrow$ most types of motion
- isokinetic (isovelocity) $\rightarrow \ldots$

3. Tetanic Twitch Simulation

(a) Derivation

1. For critically damped system $\zeta = 1$, then the Laplace transform is:

$$(s^2 + 2\omega_n s + \omega_n^2)F(s) = K\omega_n^2 U(s)$$
$$\frac{F(s)}{U(s)} = K\omega_n^2 \frac{1}{(s+\omega_n)^2}$$

2. Letting $U(s) = 1$ and taking the inverse response:

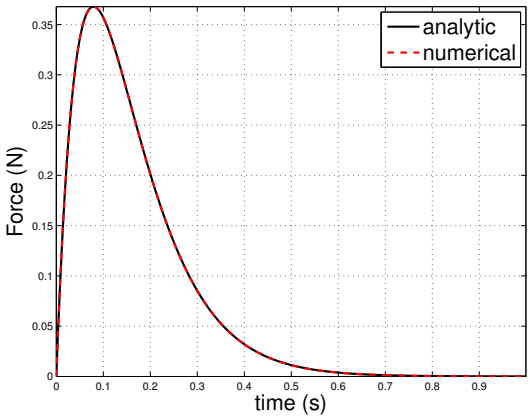
$$F(t) = K\omega_n^2 (te^{-t\omega_n})$$

let $K\omega_n = F_0$ and $\omega_n = \frac{1}{T}$ then

$$F(t) = F_0 \frac{t}{T} e^{-t/T}$$

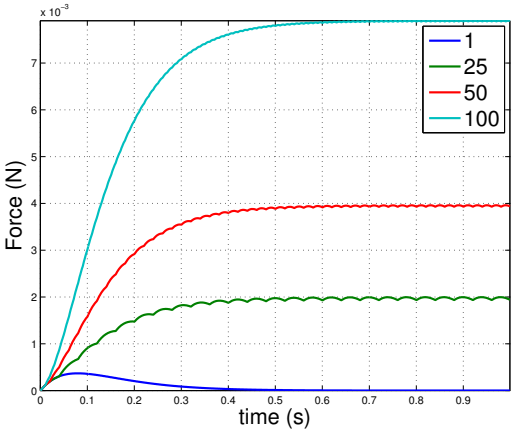
(b) MATLAB Simulation

```
% Time Vector and constansts
dt = 1/1000;
Tf = 1;
t = 0:dt:(Tf-dt);
F0 = 1;
T = 0.079;

% Analytic Model
F =@(t) F0.*(t/T).*exp(-t/T);

% Numerical Impulse Simulation
s = tf('s')
sys = (F0/T)*(1/(s + 1/T)^2);
[y,~] = impulse(sys,t);

figure; hold all;
  plot(t,F(t),'k')
  plot(t,y,'--r')
  xlabel('time (s)','fontsize',20)
  ylabel('Force (N)','fontsize',20)
  grid on; axis tight; box on;
  l = legend('analytic', 'numerical');
  set(l,'fontsize',20);
```



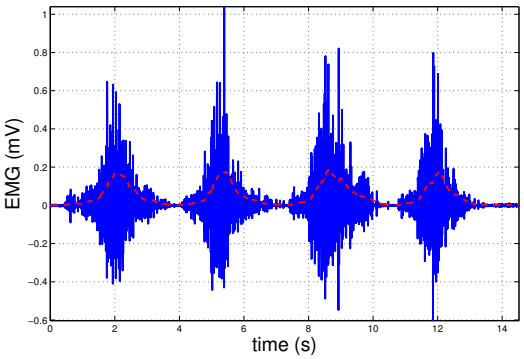
(c) Tetanic Response

```
% Tetanic Response
frange = [1,25,50,100]; % impulse freq.
figure;
for i=1:numel(frange)

  % Impulse train
  f = frange(i)
  fs = 1/dt;
  u = 0.*t;
  u(1:ceil(fs/f):end) = 1;

  [F,~] = lsim(sys,u,t);

  gcf, hold all;
    plot(t,F)
    xlabel('time (s)','fontsize',20)
    ylabel('Force (N)','fontsize',20)
    grid on
end
  gcf; l = legend('1','25','50','100'); set(l,'fontsize',20)
```

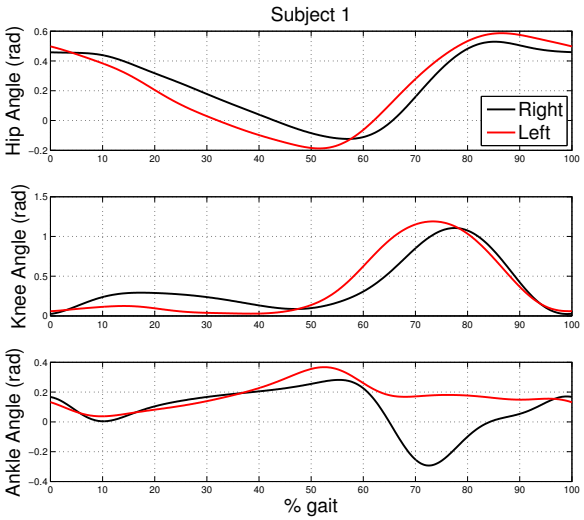


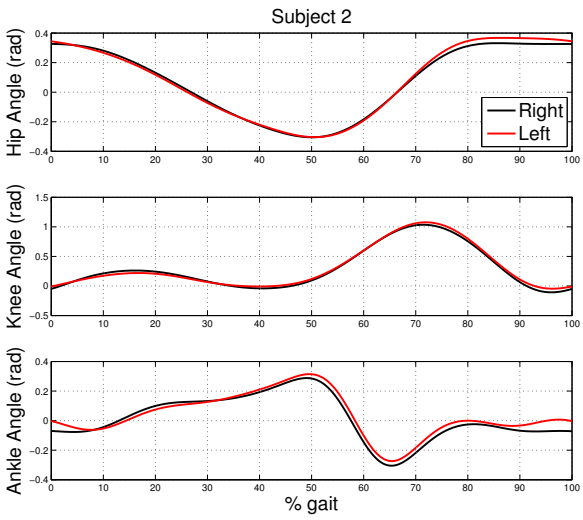
4. Linear Envelope of EMG

```
load('st_emg.mat')
fs = 1000;
t = 0:(1/fs):(numel(st_emg)*(1/fs) - (1/fs));

K = 1;
fc = 2;
wc = fc*2*pi;

s = tf('s');
sys = (K*wc^2)/(s + wc)^2;

st_rect = abs(st_emg);
[st_le,~] = lsim(sys,st_rect,t);
figure; hold all;
  plot(t,st_emg)
  plot(t,st_le,'--r')
  grid on; axis tight; box on;
  xlabel('time (s)','fontsize',20);
  ylabel('EMG (mV)','fontsize',20);
```



5. Qualitative Kinematic Analysis





6. Paper Review

Read the paper.