Optional Assignment (due: 12 Dec)

Simulation. Identify a control that maximizes gait stability for running assuming that the leg stiffness can vary between apex and touch-down (Fig. 1). **(6pts)**

1. Start with the spring-mass running simulation you have from the computer labs. Keep all parameters the same ($\alpha_0 = 68°$, $l_0 = 1m$, $m = 80kg$, $E_{sys} = \frac{m}{2}\dot{x}_0^2 + mgy_0$ with $\dot{x}_0 = 5m/s$, $y_0 = 1m$) except for the leg stiffness k. Write a matlab script that can vary the initial condition and k, then calls the simulation model, and gets the next apex state y_{i+1} back from the simulation. (1pt)

2. Embed the code in a matlab optimization which, for a given initial state y_i, minimizes by varying k the difference between y_{i+1} and y_{tgt}, where y_{tgt} = 1.05m is the target apex state. (2pts)

3. Repeat this search for a series of initial conditions and extract the relationship $k(y_i)$. Show that this function improves gait stability by plotting the resulting Poincare map and comparing it to the Poincare map with constant k = 20kN/m. Use the relationship between $k(y_i)$ and the falling time from apex y_i to touchdown $y_{TD} = l_0 \sin\alpha_0$ to transform the function $k(y_i)$ into a function $k(t - t_{apex})$ that varies the stiffness after apex. (1pt)

4. Embed this function $k(t - t_{apex})$ in your model and have it run over ground with randomly changing ground height. Scale the size of random ground height changes in successive simulations and assess the tolerance of the control against ground disturbances. Compare your assessment with the predictions of the Poincare map you obtained earlier. (2pt)

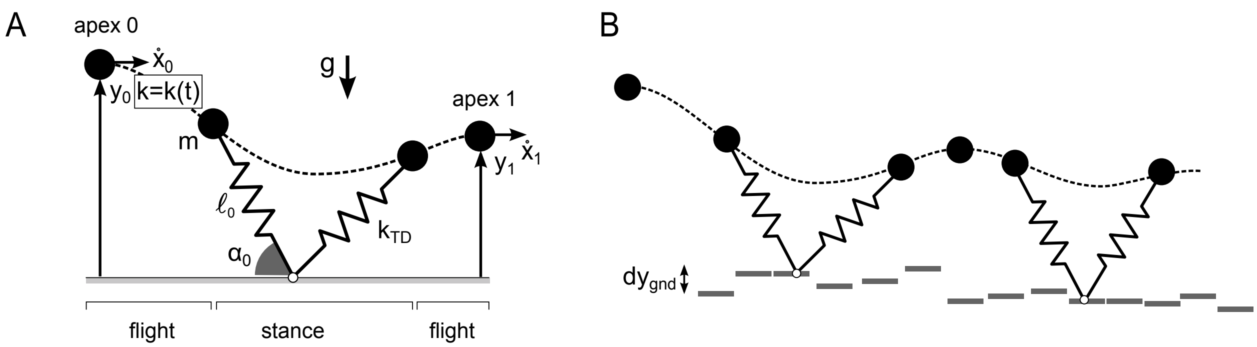

Figure 1: Active stiffness control for running stability. (A) The value of the parameter k changes during flight, but only until touch down. Once the model is in stance, the stiffness is fixed at the stiffness k_{TD} that the model assumed at touch down. (B) Running on rough ground with random step changes dy_{gnd} that stay within $\pm dy_{max}$.