Problem 1 (4.5 points):

You have been consulted by the manager of a wildlife park who is interested in controlling the population of the most popular viewing attractions in the park – the hare and the fox. The number of foxes and hares depend on their birth rates, death rates, and importantly, the foxes preying on the hares – not to mention happenstances like illness. Specifically, the manager would like the number of hares to remain at 30 each month, and wants you to develop a control algorithm that will help determine the number of foxes to be brought in or sold (if any) at the end of each month to keep the number of hares at this number. You need some data. Luckily, they have been keeping the data of the number of foxes and hares at the park every 4 weeks for the past 10 years, and intend to continue doing so. They share the data kept so far with you in the file `fox_hare.mat`. Using the data, find the optimal control algorithm that the manager desires. Explain your process. (Hint: The Lotka–Volterra equations have been known to capture prey-predator dynamics).

NOTE: There are potentially several ways to approach this problem; you will be graded based on the elegance of your solution.

Problem 2 (3.5 points):

(a) Consider Problem 1 in Homework 5. Identify the (discrete-time) system model embedded in the file `aerialVehSim.p`. Use a sampling time of 0.1s. Do not use inbuilt toolbox functions.

(b) Based on your model, design a feedback MPC for the system that will track the spiral reference given in Problem 1b of Homework 5. That is, suppose $\psi(j) = \begin{bmatrix} x(j) & y(j) & z(j) \end{bmatrix}^T$ and $r(j) = \begin{bmatrix} x_d(j) & y_d(j) & z_d(j) \end{bmatrix}^T$ denote the actual and desired coordinates respectively at time step j, your MPC should minimize the following cost at j:

$$J = \frac{1}{2} \sum_{k=j}^{j+N-1} \left(r(k+1) - \psi(k+1)\right)^T Q \left(r(k+1) - \psi(k+1)\right) + (u(k))^T R u(k),$$

where $N = 30$, $Q = 10I_p$ and $R = I_m$, I_p and I_m being identity matrices of appropriate dimensions. Assume $\psi_0 = \begin{bmatrix} 0 & 0.1 & 0 \end{bmatrix}^T$. Using MATLAB's `plot3` or otherwise, plot the desired maneuver trajectory and the actual trajectory executed by the vehicle in 3D (plot z against x and y). Compare the performance with LQR control.