Neuroevolutionary Control of an Inverted Pendulum

Problem Description

In this assignment you will develop a neuroevolutionary controller to balance an inverted pendulum on a cart, as seen in Figure 1.

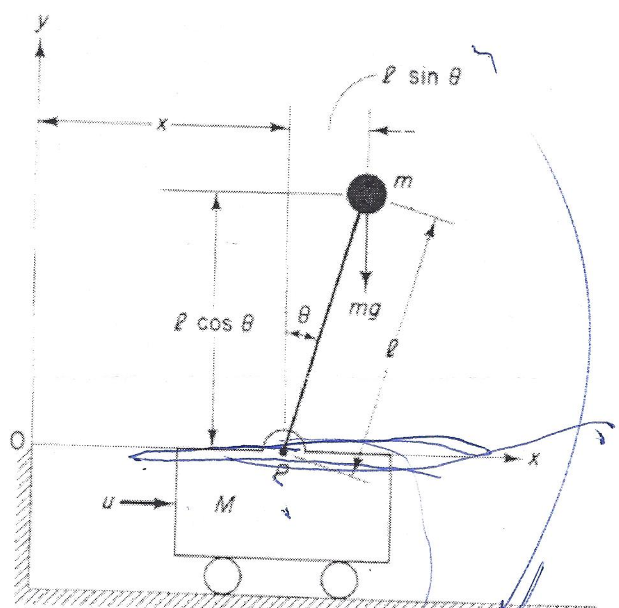

Figure 1: Inverted pendulum representation

The two governing equations for this problem are:

$$(M+m)\ddot{x} - ml\sin\theta\dot{\theta}^2 + ml\cos\theta\ddot{\theta} = u \quad (1)$$

$$m\ddot{x}\cos\theta + ml\ddot{\theta} = mg\sin\theta \quad (2)$$

where:

- M is the mass of the cart.
- m is the mass of the weight at the end of the pendulum (for simplicity, we assume the rod is massless).

- x is the lateral position of the cart.
- θ is the angle of the pendulum rod w.r.t. vertical.
- l is the length of the pendulum rod.

Tasks

Please complete the following tasks:

1. Code the system dynamics using finite-difference methods. Given a set of control actions $U = \{u_t | t \in [0, 1, ..., t_{max}]\}$, you should be able to simulate the trajectories of θ and x.
2. Evolve a neural network controller to balance the pendulum, using the simulator developed in task 1 to test the controller.

The goal is to develop a controller which can balance the pendulum as long as possible. You should develop your own fitness function to evaluate evolved controllers, but a reasonable starting point is the number of timesteps the pendulum remains within $\theta_{threshold}$ of vertical.

Network inputs should include x, $\dot{x}$, $\ddot{x}$, θ, $\dot{\theta}$, and $\ddot{\theta}$, and the network output should be u. For the system parameters, assume $M = 10kg$, $m = 1kg$, $x_{t=0} = 0$, $\theta_{t=0} = 0rad$, and $l = 1m$.

Questions to Answer

1. ~~How do different fitness functions you tried affect learning speed and solution quality? How would you characterize "good" fitness functions?~~
2. What happens if $\theta_{t=0} = \pi$ (i.e. initially pendulum is pointed straight down)? Can you train a controller to get the pendulum to vertical and then keep it there?