Exercises 4 – Fuzzy Control, Genetic Algorithm

Problem 1: Inverted Pendulum (50 + 30)

In this problem, we want to design a fuzzy controller in order to solve the inverted pendulum problem. Our pendulum is located on a cart consists of a mass M at the top of a rod of length l pivoted on a horizontally moving base. The rod is considered massless and is carrying a mass m.

For implementing the fuzzy controller, You have to write your code in `inverted_pendulum.fcl` file which is a Fuzzy Control Language file. You have to declare your needed inputs and outputs. After that, it is necessary to `FUZZYFY` and `DEFUZZYFY` the required variables, and at the end write your fuzzy rules in the `RULEBLOCK` section.

After every run, you get a report from the system that contains charts from `x` (cart position), `x_dot` (cart velocity), `x_dot_dot` (cart acceleration), `theta - 180` (pendulum degree), `theta_dot` (pendulum angular velocity), `theta_dot_dot` (pendulum angular acceleration), and `f` (force applied to the cart).

Note that theta starts from the bottom of the unit circle and goes on the counterclockwise circle. Therefore, theta value is always 90 degrees more than that of the unit circle.

Stable state: a state in which the pendulum degree, pendulum angular velocity, pendulum angular acceleration, cart acceleration, and force applied to the cart equal to 0.

(a) Design the fuzzy controller so that the inverted pendulum stay at a stable state for enough time started from a random state that every variable except the pendulum degree is 0. (50)

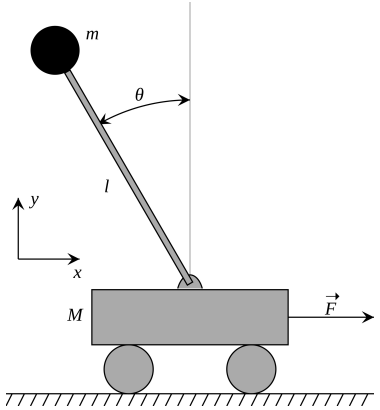
(b) *Make the cart velocity 0 while being at the stable state. (15)

(c) *Make the cart position 0 while being at the stable state. (15)

In the end, write a report and explain the fuzzy terms you have used for your variables, the way you fuzzyfy and defuzzyfy them, and your inference method. Include some report chart from random runs in your report.

Some useful webpages:

- http://pyfuzzy.sourceforge.net/doc/quickstart.html
- http://ffll.sourceforge.net/fcl.htm



Problem 2: Finding Equation Roots (50)

In this problem, we want to find a root of the following polynomial using a genetic algorithm.

$$9x^5 - 194.7x^4 + 1680.1x^3 - 7227.94x^2 + 15501.2x - 13257.2$$

Firstly, you need to select a suitable genome format for this problem. In order to do so, consider each genome as a root candidate. Note that a root may be a real number, not an integer number necessarily.

Secondly, you need to choose an appropriate fitness function. In this case, your fitness function is the distance of P(x) from 0 which is the absolute value of P(x), and obviously, you want to minimize this fitness function until reach zero which means you find the root.

Lastly, you need to implement a function to create new generations from the random first generation, and your function should use single point cross-over and mutation for creating new generations.

The number of genes in each genome is your choice but we strongly recommend to use at least 20 genes (10 for the integer part, and 10 for floating point part). Moreover, initial population size, number of cross-overs in each generation, the probability of mutation for each gene, and the population size remain from each generation are all hyperparameters, so choose them wisely!

Please pay attention to the followings:

- This homework has 130 marks. However, the questions marked by a star are considered as bonus questions and it is up to you whether to answer them or not.
- The codes are to be submitted with python and numpy module
- You should send your homework to iust.ci972@gmail.com. You only need to email a zip file named as p4_94520000_lastname.zip. The zip file should contain a document to fully explain your code and the answer to other questions, the code itself and images containing your program execution and charts.
- You should submit your homework before Tir 1st (11:59 pm Khordad 31st). You have 3 extra days to submit your homework after the given deadline during this semester. If you exceed your 3 extra days, you will lose 10 percent of your mark by each day.
- Please subscribe to our telegram channel (@CAI972) to get the latest news about your homework.

Good Luck