METU EE 496
Introduction to
Computational Intelligence

Infecting the Artificial World with Fuzzy Control

Homework 3 - Fuzzy Control

Due: 23:55, 03/05/2020

Late submissions are welcome, but penalized according to the following policy:

- 1 day late submission: HW will be evaluated out of 70.
- 2 days late submission: HW will be evaluated out of 50.
- 3 days late submission: HW will be evaluated out of 30.
- 4 or more days late submission: HW will not be evaluated.

You should prepare your homework by yourself alone and you should not share it with other students, otherwise you will be penalized.

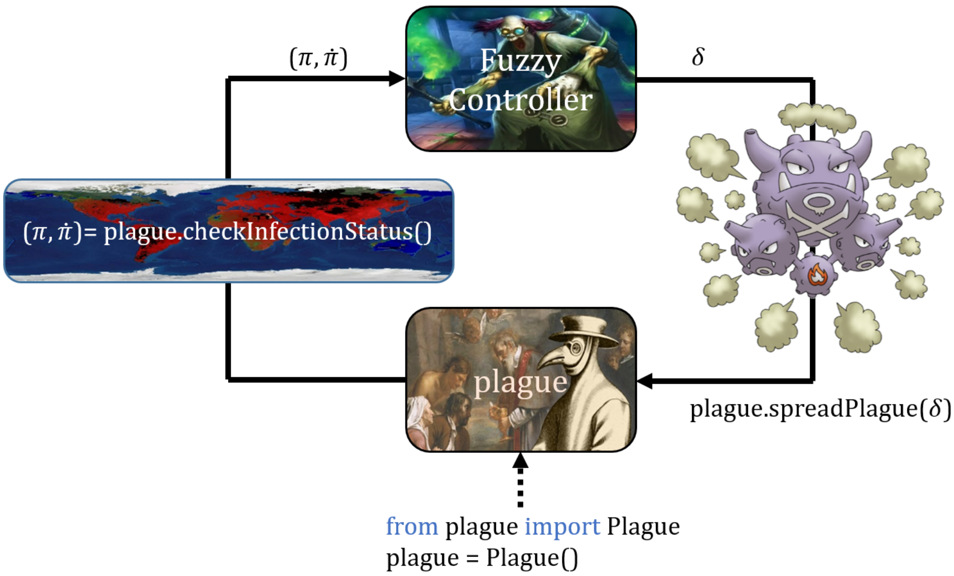

Figure 1: The flow of the controller and the plague.

Introduction

An artificial world has been created by some villains. The shocking(!) news is that their aim is to conquer the whole galaxy via the artificial world. The artificial world is very similar to ours and in that world there live human-like biological beings called *bots*. They are creatures equipped with artificial intelligence without soul (so killing them is OK!). Bots attack the planets in the galaxy to serve their masters. Thus, the planets including ours are in danger. However, our scientists and politicians have found a way to turn this situations into our advantage. They have analyzed that bots can get sick and dealing with sick bots becomes easier. Hence, they have developed a virus. Moreover, they have placed an undercover agent among the villains and that agent have founded a medicine company to sell the cure to the bots. Hence, the bots implicitly contribute to our economy by buying the medicines. In this way, we can make more investments for the developments which will protect our world from villains.

The point of the story is creating a plague in the artificial world and controlling it is utterly severe. In this homework, you will create a plague by spreading your virus throughout the artificial world. Your aim is to infect 60% of the bots in the world and maintain that percentage. In this way, your disease will not be considered significant enough by the authorities to develop a permanent cure for it and there will always be customers to your medicines.

You infect the bots by contaminating the environment with your virus. Assume that you have conducted the required research on the relation between the infection rate and the contamination amount by considering the birth-death rates as well. Hence, you are able control the infection rate in terms of percentage per day. In that manner, setting infection rate to some $x\,\frac{\%}{day}$ means that the percentage of the infected bots will be increased by x; namely, if the current percentage were p then the percentage after a day would be $p+x$. On the other hand, your research has revealed that there exists a disappearance rate for your virus owing to the symptoms of your disease and natural birth-death rates. The disappearance rate is proportional to the percentage of the infected bots. The more bots get infected, the more rapidly vanished your disease will be. You can also measure that rate in terms of percentage per day. Therefore, there is an effective infection rate which is the difference between the infected rate controlled by you and the disappearance rate. Your task is to provide proper control for the infection rate so that the percentage of the infected bots is to come to the equilibrium at 60% as quickly as possible. You will perform this task via Fuzzy Control! You see that coming...

You do not need to worry about the aforementioned dynamics of the plague to provide proper controls. You will be provided with a class named *Plague* in the *plague.py* file under *HW3* folder in *ODTUClass* course page. With that class, you are able to take measurements to determine your control and apply your control to spread the disease. The measurements are the current infected percentage and effective infection rate. You are able to control the daily infection rate of the disease by increasing or decreasing the current infection rate. For instance, if your control output were c and the current infection rate were r, then the updated infection rate would be $c + r$. Once you apply your control by calling the related method of the Plague class, the infection rate will be updated, the effective infection rate will be determined and the percentage of the infected population will be updated with those rates for 0.1 day (2.4 hours), internally. Then you can observe the updated infected population percentage and effective infection rate by simply calling the related class method. Note that you are observing changes within 0.1 day intervals. The flow of the controller is depicted in Fig. 1 together with the sample codes to be used in your implementations.

Input Variables and Control Variable

The input variables are the two measurements which are the current percentage of the infected bots,

$$\pi \in [0, 1]\,,$$

and the current effective infection rate,

$$\dot{\pi} \in [-1, 1]\,.$$

The control variable,

$$\delta \in [-0.15, 0.15]$$

is the infection rate to be added to the current infection rate. Note that the control variable allows to increase or decrease the infection rate and its maximum magnitude is limited to 0.15.

While providing your control to the Plague class, you do not need to consider whether the percentage will exceed 1 or drop below 0. Those are internally handled within the class. Similarly, you do not need to consider whether the infection rate will exceed 1 or drop below -1 as well.

Homework Task and Deliverables

In the scope of this homework, your task is simply to implement a fuzzy controller which takes two input measurements and provides one output control (Fig. 1) to quickly infect the 60% of the bots and maintain that percentage. You will practice on set partitioning and fuzzy control rules to determine your own partitions and decision logic. The details on the sets where the measurements and output control lie will be provided in the next section.

The homework is composed of 2 parts. In the first part you are to design your controller without using effective infection rate measurements. In the second part, you will update your design to take effective infection rate measurements into account. In both parts, you will estimate some performance metrics and you will provide the results by some visuals. Finally, you will compare the two controllers and interpret the results by your own conclusions.

You should submit a single report in which your answers to the questions, the required experimental results (performance curve plots, visualizations etc.) and your deductions are presented for each part of the homework. Moreover, you should append your Python codes to the end of the report for each part to generate the results and the visualizations of the experiments. Namely, all the required tasks for a part can be performed by running the related code file. The codes should be well structured and **well commented**. The submissions lacking comments will be simply not evaluated.

The report should be in portable document format (pdf) and named as *hw3_name_surname_eXXXXXX* where *name*, *surname* and Xs are to be replaced by your name, surname and digits of your user ID, respectively.

1 Plague v1

In this version of the plague, you have not researched the disappearance rates yet. Thus, you can only measure the current percentage of the infected bots. In this manner, design a fuzzy controller which takes π as the input and provides δ as the output to infect 60% of the bots and maintain that percentage.

1.1 Set Partitioning

Partition the sets where the measurement and the output lie into **3** fuzzy sets. Namely, you are to represent $[0, 1]$ and $[-0.15, 0.15]$ with three fuzzy sets for each. You may experiment on different partitioning strategies by examining the performances. Decide your favorite partitioning and plot your fuzzy partitions for both sets in Python and include them in your report. Explain how you decide that partitioning.

1.2 Fuzzy Control Rules

Considering your partitions, list your control rules.

1.3 Fuzzification and Defuzzification Interface

Implement your controller in Python. Explain how you implement the fuzzification and defuzzification interface.

1.4 Simulation

Using your controller and the Plague class, spread your virus for at least 20 days. In other words, perform at least 200 iteration of control. You may increase the number of iterations if you fail to observe the equilibrium.

Now, you are not sure whether your plague behaves efficiently. You benefit from your disease when your reach 60% of infection and maintain that percentage. Until then, unit infection percentage is considered to have unit cost. You will compute the total cost until the equilibrium. Your performance measures will be that infection cost and the number of days passed until the equilibrium. To compute those measures:

1. Estimate the iteration number where the plague comes to an equilibrium at 60%. You can use *infected_percentage_curve_* attribute of the Plague class to obtain the percentage curve.
2. Compute the infection cost until the equilibrium. You can use *infection_rate_curve_* attribute of the Plague class to obtain the curve of the infection rate consumed during the spread process.
3. Visualize your plague by using the *viewPlague* method of the Plague class. You should provide iteration number you find in Step 1 and the cost you computed in Step 2 to that function in order to properly visualize the plague. Add that plot to your report.

2 Plague v2

You decide to conduct research on the disappearance rates to develop your plague after you have observed the behavior of the previous version of your plague. You want to decrease the overshoot and increase the convergence rate to the equilibrium. You have made your research and now you can measure the current effective infection rate which is the difference between the controlled infection rate and the disappearance rate. In this manner, design a fuzzy controller which takes π and $\dot{\pi}$ as the inputs and provides δ as the output to infect 60% of the bots and maintain that percentage.

2.1 Set Partitioning

Partition the sets where the measurements lie into **3** fuzzy sets. Namely, you are to represent $[0, 1]$ and $[-1, 1]$ with three fuzzy sets for each. Partition the output set into **5** fuzzy sets $[-0.15, 0.15]$. You may experiment on different partitioning strategies by examining the performances. Decide your favorite partitioning and plot your fuzzy partitions for both sets in Python and include them in your report. Explain how you decide that partitioning.

2.2 Fuzzy Control Rules

Considering your partitions, list your control rules. You may experiment on different set of rules by examining the performances. Decide your favorite set of rules and list them. Explain how you decide that rule set.

2.3 Implementation and Simulation

Repeat 1.3 and 1.4 for this version of the plague.

2.4 Comparison

Considering the performance measures and the behavior of the percentage curves, compare two versions of the plague. State the differences and discuss.