ASSIGNMENT 1: AGENT BEHAVIOUR SIMULATION

Date of hand out	08. September 2022
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Course	Agent-based simulation, 42188
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Please read the whole handout before starting as there are notes at the end.

Your hand-in should be a maximum of 12 pages Pdf document that can be read alone. A Notebook should be provided as supplementary material.

Problem 1 (50 points)

Data/code: The Swissmetro dataset (`swissmetro.dat`)

This dataset consists of mobility survey data collected on the train between St. Gallen and Geneva, Switzerland, during March 1998. The respondents provided information in order to analyze the impact of the modal innovation in transportation, represented by the Swissmetro (SM), a revolutionary mag-lev underground system, against the usual transport modes represented by car and train.

Tasks (3 Questions)

You are asked to simulate the demand for different policy scenarios using the an already estimated model for mode choice in inter-urban trips in Switzerland. Estimated coefficients of a discrete choice model should be used to simulate the choice probability of each alternative for each agent in a given sample. Here, we will also be interested in the aggregate market shares (% of people selecting each alternative) for the entire population and for different segments of the population. The simulation model should also be used to look at how these aggregate market shares are affected by a change in an independent variable, i.e. to possible policy scenarios. More specifically, please carry out the following tasks:

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1) Create an utility-maximizing agent that decides on the mode (CAR vs TRAIN vs SM) to take given a set of alternative (mode) specific attributes and its own (agent) internal characteristics. The agent's action follows the **multinomial logit** choice model below:

$$V_{car} = -0.608 - 0.0111 \times CAR\_TT - 0.00936 \times CAR\_CO - 1.88 \times SENIOR$$

$$V_{train} = -0.0111 \times TRAIN\_TT - 0.0268 \times TRAIN\_CO - 0.00586 \times TRAIN\_HE + 0.557 \times GA$$

$$V_{SM} = -0.135 - 0.0111 \times SM\_TT - 0.0104 \times SM\ COST - 0.00586 \times SM\_HE - 1.88 \times SENIOR + 0.557 \times GA$$

where CAR_TT is the car travel time, CAR_CO is the car cost, $TRAIN\_TT$ is the train travel time, $TRAIN\_CO$ is the train cost (considering the ownership of Swiss annual season ticket, GA), $TRAIN\_HE$ is train headway (in minutes), SM_TT is the Swissmetro travel time, SM_CO is the Swiss- metro cost (considering the ownership of GA), SM_HE is the Swissmetro headway, $SENIOR$ is a dummy variable for senior people (age above 65[1]) and GA a dummy variable that captures the effect of the Swiss annual season ticket for train.

2) A. Compute the estimated market shares by both **sample enumeration** and **simulation** for the entire sample provided in the data file (N=10728).
   B. Comment on both their values.
   C. Compare against the observed market shares (computed using the CHOICE variable in the data set).
3) Suppose that we know that market segmentation exists on income. We can then consider three markets, namely, low income, medium income and high income that are defined as follows:
   - Low Income: under CHF 50,000 (INCOME = 0 or 1)
   - Medium Income: between CHF 50,000 and CHF 100,000 (INCOME = 2)
   - High Income: Over CHF 100,000 (INCOME= 3).

We would like you to investigate the cost influence on the market shares of Swissmetro. Change the cost for the Swissmetro between -20% and 20% and forecast the market shares for each income category after this change. Please comment.

Note: In the Swissmetro dataset, you will observe that each agent (ID) has made 9 choices. Please consider them independent and equally weighted for the computation of market shares.

[1] A few observations, where the variable AGE is unknown (coded as 6) can be removed from the simulation.

Problem 2 (50 points)

<u>Data/Code:</u> The Wolf Sheep Predation (`Wolf-Sheep.ipynb`)

In this Problem you will analyse and extended an existing simple ABM model, the Wolf-Sheep Predation model[2] and its implementation in `Mesa`[3] . For a smooth learning of `Mesa` please take your time in going through the first steps here: https://mesa.readthedocs.io/en/latest/overview.html.

This model explores the stability of predator-prey ecosystems. Such a system is called unstable if it tends to result in extinction for one or more species involved. In contrast, a system is stable if it tends to maintain itself over time, despite fluctuations in population sizes.

Wolves and sheep wander randomly around the landscape, while the wolves look for sheep to prey on. Each step costs the wolves energy, and they must eat sheep in order to replenish their energy - when they run out of energy they die. To allow the population to continue, each wolf or sheep has a fixed probability of reproducing at each time step. The sheep must eat grass in order to maintain their energy; when they run out of energy they die. Once grass is eaten it will only regrow after a fixed amount of time. This variation is more complex than the first, but it is generally stable.

Parameters:

- `initial_sheep`: The initial size of sheep population
- `initial_wolves`: The initial size of wolf population
- `sheep_gain_from_food:` The amount of energy sheep get for every grass patch eaten
- `wolf_gain_from_food:` The amount of energy wolves get for every sheep eaten
- `sheep_reproduce`: The probability of a sheep reproducing at each time step
- `wolf_reproduce`: The probability of a wolf reproducing at each time step
- `grass_regrowth_time`: How long it takes for grass to regrow once it is eaten

<u>Note</u>: One unit of energy is deducted for every step a wolf takes and one unit of energy is deducted for every step a sheep takes

<u>Tasks (4 Questions)</u>

1) Identify the system's states, agents, actions and rules.
2) Run the model a few times. How do the sizes of the three populations appear to relate in time? **Please explain** and provide a plot /numerical table to sustain it.

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[2] Wilensky, U. (1997). NetLogo Wolf Sheep Predation model. http://ccl.northwestern.edu/netlogo/models/WolfSheepPredation. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

[3] https://github.com/projectmesa/mesa/tree/master/examples/wolf_sheep

3) Select 3 parameters above of your choice. What is the relationship between each of these 3 parameters and the stability of the ecosystem (number of sheeps and wolves in the long-term). **Please explain** and provide plots / numerical tables to sustain it.
4) Change the rules in `sheep_reproduce` and `wolf_reproduce` so that reproduction only occurs if the animal's energy level is above a particular level (new parameter). Pick some initial default value (hint: try 16). What happens to the relationship between wolf, sheep, and grass populations as you change the minimum energy level for reproduction?

Note2: Don't forget you are running a stochastic ABM model, thus more than one replication may be helpful, and stability conditions depends on how long you run it.