CS166 Assignment 2
Traffic simulation

In this assignment, you will build cellular automata to model traffic flow.

Each cell is about the size of a car and cars travel along a road, passing other cars if they can. You will see how cellular automata can be used to model some realistic traffic patterns and explore what happens if driver behavior changes.

Part 1: Traffic jams on a circular road

We work through this model in class in sessions 4.1 and 4.2. You should use the pre-class work and discussions and problem-solving sessions in class to complete most of this part of the assignment. In the next part, we extend this model to more realistic situations.

For Part 1, implement the single lane, variable-speed traffic model described in Nagel, K., Schreckenberg, M. (1992). A cellular automaton model for freeway traffic. *Journal de Physique I, 2*(12), 2221–2229.

- Write well-structured and well-documented Python code to implement the model described in the paper.
- Visualize the state of this model over time, to show how traffic jams can appear when traffic density is high enough.
- Analyze how the overall average traffic flow rate varies with traffic density and present your results in your report.

Part 2: Multi-lane highways

Implement the 2-lane, symmetric, uni-directional, variable speed model in Rickert, M., et al. (1996). Two Lane Traffic Simulations using Cellular Automata. *Physica A: Statistical Mechanics and its Applications, 231*(4), 534–550.

We start looking at this model in class and you will have an opportunity there to share ideas and discuss problems you encounter. You will need to complete this part of the assignment on your own though.

- A description, in your report, of how this model works. What are the assumptions, parameters, and update rules of the model? Do not just copy and paste from the paper. Explain the cellular automaton in your own words and as clearly as possible.
- Write well-structured and well-documented Python code to implement the model described in the paper.
- Visualize the state of this model over time, to show the typical traffic patterns that can emerge. Your results will again depend on traffic density.
- Analyze how much more traffic can flow through a multi-lane road, compare to a single lane road, at the same traffic density. Present your results in your report.

Key questions

You have to address all of these questions in your report. You should use your results from both Part 1 and Part 2 to formulate your answers.

- How much more traffic can flow through a 2-lane road compared to a 1-lane road at the same traffic density? What about roads with more than 2 lanes? Either model 3 or more lanes and report on your results, or predict how much larger the traffic flow through a 3+ lane road will be compared to a 1-lane road at the same traffic density.
- How applicable is this model to traffic in Buenos Aires/Taipei? (If you are not in Buenos Aires or Taipei, comment on how applicable the model is to traffic in your city.) Write a short paragraph and motivate why the model is suited to traffic in your city (or why it is not).

Stretch goals (Optional)

All of these goals are open-ended. You may attempt one or more of them, but rather attempt one goal in-depth than attempting multiple goals superficially. If you discover something interesting, please include that in your report with supporting code, text, and plots to explain what you found. Innovative or interesting results that are explored in-depth and presented well will score a 5 on one or more of the assignment's learning outcomes.

- Stretch goal 1: Describe and analyze how good and bad driver behaviors affect traffic flow and traffic jams on multi-lane highways. In order to analyze behavior, you will need to encode bad driver behavior in your cellular automaton update rule, run the simulation and report on how particular behaviors affect traffic flow and traffic jams. Key question: What do your results imply about how self-driving cars should be programmed?
- Stretch goal 2: Extend your model to include a speed limit, traffic lights, obstacles, and lane merges. The speed limit should be defined at every cell so that different parts of the road can have different speed limits. This allows you to model how a change in the speed limit at a point in the road affects traffic at, before and after that point. Traffic lights can be modeled as a temporary speed limit of 0 on a portion of the road, changing to and from the normal speed limit at regular intervals. Obstacles are like having a permanent stationary car at a particular cell. Model how cars have to go around an obstacle (e.g. accident) in the road. Lane merges can be modeled as a very long obstacle blocking a lane. Simulate, visualize and analyze the effects of speed limit changes, traffic lights, obstacles, and lane merges on traffic flow.

Work product

- A Python notebook with the code and output (text and plots) for Part 1 and Part 2. Your code should be neat, well-organized, and documented.
- A neatly presented PDF report, comparing the traffic flow vs traffic density results from Part 1 and Part 2. You should interpret these results in your report by answering the key questions.
- Make sure you address all points under Part 1 and Part 2 above, like explaining how the model works.
- You have to address all of the key questions in your report.
- Conclude your report with a *Future Work* section. How could you further extend your model(s) to represent more realistic traffic situations?

Please typeset your work and submit your report as a PDF file, along with a Jupyter notebook containing your code and any output (text or plots) generated by running the code. You may zip your .ipynb file if necessary; do not zip your PDF file before uploading it.

- Make sure that you submit a neat, clearly presented, and easy-to-read report.
- Also remember to comment your code, with the goal of making it easier to understand what the purpose of each part of the code is.
- You will get a #professionalism score on every assignment.
- Remember to mention any additional HCs that you use or reference in your work.