Improved Macroscopic Traffic Flow Modelling with Cellular Automata

Noah Gardner*
ngardn10@students.kennesaw.edu
College of Computing and Software Engineering
Marietta, Georgia, USA

Andy Vu*
avu5@students.kennesaw.edu
College of Computing and Software Engineering
Marietta, Georgia, USA

Olivier Tran*
otran@students.kennesaw.edu
College of Computing and Software Engineering
Marietta, Georgia, USA

Sanjeev Khemani*
skheman1@students.kennesaw.edu
College of Computing and Software Engineering
Marietta, Georgia, USA

Abstract

This paper is based on another research paper in cellular automata in which city traffic and its affection by factors such as distributed occurrence, evanescence, and time variation is observed on a two-dimensional grid. The variables used in this new experiment include diagonal paths, one-way streets, pre-generated flows, varying speeds, varying destination priority, and different types of roads. With these additional factors in the experiment, the results of the new simulation may yield results that more accurately reflect the environment of real-world traffic.

Keywords: traffic flow, cellular automata

ACM Reference Format:
Noah Gardner, Andy Vu, Olivier Tran, and Sanjeev Khemani. 2018. Improved Macroscopic Traffic Flow Modelling with Cellular Automata. In *Proceedings of ACM Conference (Conference'17).* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/1122445.1122456

1 Research Statement

There are a few interesting changes we could make to the original algorithm in order to explore the impact of different traffic environments and flows. For example, the original paper randomly generates *traffic flows* which are an abstracted representation of the traffic that actually represents a group of vehicles as a random amount of traffic. Additionally, when each traffic flow is generated, the destination of the flow is also generated randomly. After the traffic flow is generated and the destination is chosen, the traffic flow chooses it's path automatically as the shortest distance from the starting cell to the current cell. Finally, the original paper uses one traffic environment with simple two-way roads that are placed on the grid laterally and vertically.

One idea we would like to explore is to add different priorities for cells as destinations. If a cell is a high priority destination, then it is more likely to be chosen as a destination for a traffic flow when it is generated. Another improvement could also allow for modelling of different types of roads. For example, rather than the flow taking the shortest path from the source to the destination, each cell could have a parameter for the weight of adding that cell to the path of the traffic flow. If the weight of adding the cell to the path is low, that cell may be modeled as part of a road that can handle more traffic such as a highway. The original experiment also did not test diagonal or one-way streets, so that may be valuable for a traffic flow model as well.

2 Literature Review

- Simulation of urban macro-traffic flow based on cellular automata [4]
  This paper uses a cellular automata model to simulate traffic flow on a two-dimensional grid. Traffic flows are randomly generated that have a certain amount of traffic (low or heavy) and also have a random destination. There exists a grid with cells filled in which are meant to model the roads for the traffic flow to move on. On each timestep, the traffic flows move towards their destination using a minimum distance method. The cells can hold a certain amount of traffic capacity. When the traffic capacity for a cell is reached, the cell will not allow new traffic flows to enter the cell. The cells also have a traffic volume, which helps the programmer to see at a glance which cells have high and low volumes of traffic.
- A cellular automaton model for freeway traffic [3]
  Nagel and Schreckenberg have gone away from the typical fluid dynamical approaches to traffic flow

*All authors contributed equally to this research.

Conference'17, July 2017, Washington, DC, USA

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/1122445.1122456

studies during this time to the use of a more revolutionary technique. The need for this was to introduce a factor of laminar start-stop waves with increasing vehicle density with an emphasis on human behavior a traffic environment. In their model, it is represented as a single dimensional array where each cell may be a vehicle with functions to accelerate, slow down, as well as randomized velocities. These functions are to represent the randomness in human behavior and varying conditions that are expected during traffic. The authors concluded that a computational way to simulate traffic flow, was more advantagous to a fluid dynamical approach that incorporated real world behavior of a driver but also retained the key aspects of fluid dynamic studies.

- Self-organization and phase transition in traffic-flow model of a two-lane roadway [2]
  Nagatani implements a two lane model as an extension of a one dimensional cellular automaton to monitor lane changing. Their model is essentially two 1-dimensional lattices to represent a two lane roadway. Rules using arrows within the lattice were deteremined to allow cars to change lanes at certain times such as when a car in front was blocking the path to progress forward from either the right to left direction or vice versa. These rules were dependent on the time step. Overall the results showed that as the cars general velocity increased, there was a usage of lane shifting without cars obstructing progress. As density increases, the maximal velocity decreases. There was a "sweet-spot" indicating the optimal amount of lane changing within a set of density of traffic where lane changing peaked with a critical value of density. If the density fell or rose too high, this optimal amount of lane changing dropped.
- Multi-value cellular automata model for mixed bicycle flow [1]
  Instead of car and vehicle traffic like the other papers, this paper focused on mixed bicycle flow using a multi valued cellular automata. Here the authors implemented two bicycles with different maximum speeds. The usage of bicycles to compare to vehicles have an emphasis on the behavioral and personality aspect that can be difficult to analyze with cars. The authors explain that young riders tend to ride at high speeds while older riders ride at a lower speed. These differences show that there is no set maxium velocity. In this model, bicycles can move to their next open site with faster bicycles moving with priority over slower bicycles. It was shown similarily to vehicles that slow bicycles that congregate and occupy sites, block faster moving bicycles that cannot overtake and thus move in a platoon order. Increasing slow bicycle density will congest and bottleneck the simulation. One of the points that B. Jia and the authors mention that cannot be properly analysed is the nature of riders that group together because they are classmates or friends thus this simulation does have some flaws. Increasing randomization of the locations and density of slow riders tended to allow more free flow and less bottlenecking.
- Cellular automaton model for bidirectional traffic [5]
  Simon and Gutowitz have built upon the paper referenced above by Nagel and Schreckenberg. Here they are implementing a bidirectional traffic using a two lane road with traffic moving in opposite direction in comparison to Nagel and Schreckenberg's one lane cellular automaton. They have incorporated inteteractions to simulate passing, as well as a distribution of varying vehicle speeds. Once again, Simon and gutowitz, like their reference model, had an emphasis on approximating the behavior of real traffic and human behavior. They wanted to address the issue of a one lane cellular atomaton where all vehicles have a maximum velocity and thus the model unrealistically follows a lead slow car, hence the need and emphasis on passing. The bidirectional model varried in types where there was varrying rules regarding passing. The researchers have found that passing greatly increases fluidity in traffic not seen in single dimensional cellular automaton and greatly resembles real world traffic dynamics and flow.

3 Methods

For this project, we plan to use Python to implement our cellular automata traffic flow model. We may also include a GUI to visualize the traffic flow on each time step. This section will be expanded as the project progresses.

4 Milestones

Date	Milestone
9/24/2021	**Project Deliverable 1**
10/8/2021	Implement the original algorithm
10/15/2021	Add weights to the cells
10/22/2021	Add destination priorities
10/29/2021	**Project Deliverable 2**
10/29/2021	Model different traffic environments (one-way, etc.)
11/12/2021	Collect experimental results and present findings
12/2/2021	**C-Day Presentation**
12/3/2021	*Optional* Add GUI to visualize the traffic flow
12/3/2021	**Project Deliverable 3**

5 Project Management

Our project has already set up weekly meetings in order to share progress and updates, and we schedule ad-hoc meetings when necessary. Additionally, we have our project inside of a github repository, where we can easily share our updated code. We plan to make use of pair-programming sessions, where we can collaborate while also sharing the load of programming.

Members' Roles

- **Andy Vu:** Programming, Writing
- **Olivier Tran:** Programming, Writing, Submitting Documents
- **Sanjeev Khemani:** Programming, Writing
- **Noah Gardner:** Programming, Writing, Source Control

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