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PHY196 Emergance in Nature

3 December 2023

In growing up, being in, and working in a larger urban area, I am no stranger to traffic jams as anyone would be in a comparable area. Before I came here to the University of Toronto, I was a part-time pizza delivery driver in the close suburbs of Chicago. Shift to shift I only had one recurring enemy, Traffic. For not only delivery drivers, the issue of the traffic jam has been a big problem for urban planners, engineers, commuters, and physicists alike. As urban areas grow and populations increase, achieving a proper and thorough understanding of traffic jams becomes increasingly more and more important. Through my research, I have found a much better understanding of the theory of traffic jams, than what is learned in our class book, *Deep Simplicity* by John Gribbin, and I explored not only how they are formed, but solutions to alleviate this modern-day inconvenience as well.

Thinking simply, in the mind of say an economist, a traffic jam is when the demand for road space exceeds its supply. However, the reasons behind the imbalance of traffic and the creation of traffic jams have many different modes and combinations making the traffic jam itself much more complicated than one could have thought. As learned in pages 158-159 of *Deep Simplicity,* one of the main contributors is the addition to the already large amount of vehicles on the road. Urbanization is constantly getting more popular, and the number of cars being added to the competition for space in a limited amount of roads is intensifying, creating a breeding ground for congestion. Human behavior also has a major role in causing traffic jams, there doesn't have

to be a major accident to cause a traffic jam. As learned the butterfly effect of a driver doing something like tapping their brakes briefly or maybe accidentally cutting someone off can turn into a ripple effect, causing the person behind them to slow down, and the person behind them to slow down, and so on creating a traffic jam. This is what is known as "phantom traffic jams," which highlights the relationship between small individual driving decisions and traffic as a whole.

Math is a tool that can provide a clear path through which we can analyze and understand things in general and when it comes to the patterns of traffic flow. The mathematical field of traffic flow theory has many complicated models and equations to show why the movement of vehicles on roads is the way they are. One thing that seldom of these models forget to feature is the traffic density measured as the number of vehicles per unit of road length. One of the more recognized models in the field of measuring traffic flow is the Lighthill-Whitham-Richards (LWR) model, which interestingly treats traffic as fluid flow. The model can show the buildup of traffic density and velocity at defined positions and times, which helped researchers point out places where traffic jams may happen. This whole, or macroscopic, tool creates valuable ways to show the systemic behavior of traffic however, it falls short in capturing the highly unpredictable individual-level, or microscopic, interactions that contribute to traffic jams.

Although unpredictable, as featured in our class book, Gribbin goes over how the frequency of these microscopic mistakes and the severity of the traffic jam follow a pattern. The relationship that is seen is the 1/f noise model. This proves that any trigger of a traffic jam has the possibility to cause any size of said traffic jam, with larger more severe congestion happening less often and less severe jams happening more frequently. Moreover, the game theory we have learned through Gribbin's book is also relevant to traffic jams. Models relevant to game theory

and traffic are used to show interactions between drivers, considering a driver will only do what is in their own best interest.

The integration of cars driven by AI into our shared roads introduces a big change in our view of combating traffic jams. Autonomous vehicles, or self-driving cars, are equipped with the sensors and communication capabilities to have the potential to help benefit traffic flow efficiency. Another new technology called adaptive cruise control, a technology that is already available in most new vehicles, enables cars to communicate with each other and adjust their speeds collectively. This behavior of cars working together holds promise for mitigating what has been figured out as the domino effect of causing slight disturbances that often lead to traffic jams.

The creation of a thing called Intelligent Transportation Systems (ITS) provides a hopeful way on how to minimize traffic jams. ITS takes advantage of newly available tech, such as real-time traffic monitoring, vehicle-to-vehicle communication, and advanced traffic signal control algorithms. The systems enable smooth and highly convenient ways of managing traffic one would not even think twice about. ITS allows for adaptive signal timing depending on real-time traffic, congestion detection, and rerouting strategies. For example, new traffic signals use real-time collected data to optimize signal timings, reducing unnecessary stops and promoting a smoother flow of traffic. Further, navigation apps that are used in the day-to-day life of many people use live traffic information that gets the individual drivers to make route choices, spreading out traffic and minimizing congestion on heavily traveled routes.

The theory of traffic jams has way deeper complexities than one may think, from a driver's own behavior to the dynamics of all traffic flow. Mathematical models, the analysis of one's behavior driving through traffic, and recently invented technologies all combine and help

create our understanding of traffic in regards to congestion and its potential solutions. As the buildup of urban areas continues and transportation technologies advance, the need for strategies to take care of traffic jams becomes more and more urgent. The creation of Intelligent Transportation Systems and the uprise of autonomous vehicles make many positive ways to address the problem of the traffic jam, but overall simply an approach that considers both the microscopic and macroscopic aspects of traffic to fix it is essential. Ultimately, traffic jams are more complex than I could have thought. Fixing them requires the collaboration of many people from many fields. The knowledge of mathematicians, engineers, computer scientists, and urban planners are all necessary concerning this deep and complex problem. By embracing a collective approach, there is hope for more efficient, sustainable, and congestion-free traffic in the future.

Works Cited

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