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BIG DATA SIMULATION: TRAFFIC SIMULATION BASED ON SENSOR DATA

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ABSTRACT

Big data analytics and scalable simulation modeling can be used to improve complex systems and processes. The explosive growth in the amount of available data for science and engineering in the coming years will enable large scale, methodological decision making. For example, due to their high cost, careful planning of improvements to transportation systems is essential. For this problem, large amounts of sensor data from roads can be used for calibrating traffic models via optimization. In this paper, we examine the problem of traffic light synchronization in an effort to improve the efficiency of road systems.

1 INTRODUCTION

Because of the availability of large quantities of data, for example over the web, new challenges are appearing for simulation. Some examples include simulating weather and climate systems, supply chains, response to health crises, and strategies for military actions.

One area where simulation optimization can be applied is in traffic light synchronization. Efficiently routing traffic through a complex road system is important as populations and cities continue to grow. Data collected from sensors can power simulations used for optimizing traffic light timings, and due to the large amount of data, as well as the complexity of the road systems, this will require Big Data techniques.

We aim to synchronize traffic lights with a microscopic simulation using real world data to drive vehicle creation and navigation patterns, and then apply optimization techniques to minimize average travel times.

2 TRAFFIC LIGHT SYNCHRONIZATION

Daily commutes, post-event traffic, and commercial deliveries all depend on an efficient road system. Traffic light synchronization is crucial to constructing such a road system.

Some approaches focus on modeling a road system using cellular automata and optimizing using machine learning techniques such as swarm methods (de Oliveira and Bazzan 2006), and reinforcement learning (Wiering, Vreeken, van Veenen, and Koopman 2004). There have also been efforts made to use stochastic optimization techniques including gradient methods (Prashanth and Bhatnagar 2012).

Our approach uses real-world data to power microscopic simulations which are used by the optimization algorithm. We obtained vehicle count data from a set of busy intersections in Kenmore, WA, USA.

3 BIG DATA SIMULATION

We create our model by fitting the data with a polynomial using regression analysis. This polynomial forms a basis for a Non-Homogeneous Poisson Processes (NHPPs). Poisson Processes are accurate models for discrete-event arrival times, but are not valid for systems with multiple busy periods. NHPPs can be given a vector of rate parameters distributed throughout the time window for the model (Leemis 2003). We used the value of the fitted polynomials to create NHPPs that serve to introduce vehicles into the model in a way that accurately reflects reality.

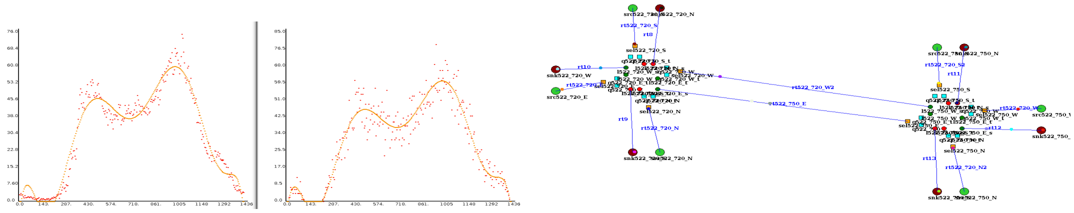

Figure 1: On the left: A comparison of the polynomial fit on the real data and the simulated data. On the right: An example animation capture for our traffic model.

4 SIMULATION OPTIMIZATION

The simulation model was created using ScalaTion (Miller, Han, and Hybinette 2010), a scalable simulation platform written in the Scala programming language. Vehicles enter the model at Sources and exit at Sinks. They travel along Transports which connect the various components in the model. As vehicles approach intersections, they pass through Selectors, which use discrete random variables based on the data to decide which direction vehicles should take.

We optimize by creating a function $f(\mathbf{x})$ where $\mathbf{x}$ represents specific timing values. x_0 represents the overall cycle length. x_1 represents the timing of green lights on the main road. x_2 represents the ratio of total green time turn lights are on. x_3 through x_6 are offset timings for other intersections. The function's scalar output is the average travel time within the model. The optimizer takes the function f and an initial $\mathbf{x}$ and runs through the BFGS Quasi-Newton algorithm. It uses an approximation to the Hessian and the gradient of $\mathbf{x}$ to find a search direction. It then performs a line search to determine how far to move in that direction. Finally, it moves to the new point and updates the approximate Hessian.

Our preliminary findings indicate that our method does work for the purposes of optimizing traffic light signals as there is a clear improvement shown after running the algorithm. The optimization process requires many simulation runs, so future work will focus on Big Data techniques to efficiently run many simulation instances. For example, simulations are largely independent, and can be executed in parallel, which will greatly improve efficiency. We will also work on refinements to the model, as well as the constraints for the optimization. Determining whether or not the minima obtained are truly global minima will also be addressed.

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