

Unbiased Simulation of Traffic in Road Networks

Uniform Sampling of Shortest Paths in Graphs

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1 Context

Graphs are mathematical structures used to represent relationships between objects. They have a wide range of applications in various fields such that computer science, social sciences, transportation, biology [3, 5, 7, 8].

In transportation networks, graphs model the flow of goods, information, and people in transportation and supply chain networks [1].

A simple model of road traffic is to represent a city or a region with a graph structure where links represent streets and nodes junctions. Then, the traffic can be modeled by considering travels being made on geodesics (shortest paths) [10]. The traffic is then seen as a dynamic process on top of the graph structure where vehicles can simultaneously be regarded as distributed at random along a road and in time. The idea is then to simulate the traffic and analyze various aspects of traffic behavior such as congestion. For instance, it is possible to assign a capacity to each node or link and when simulating the traffic we can check for parts of the graph that are congested i.e overloaded nodes or links. See Figure 1 for an example: all routes start on their first node at time 1 then on time 2 node a and b have 1 vehicle in them, c has 4 vehicles in it, d has 3 vehicles, e has 1 vehicle, f has 2 vehicles, and g has 0 vehicle. As a result node c is the only congested node at time 2.

2 Objectives

In this project, **from a theoretical point of view we want to design and analyze algorithms for the uniform sampling of shortest paths on graphs**. One way of achieving this goal is by using an unranking method or a recursive generation [9] both essentially assigning an integer to each shortest path and then by uniform sampling of an integer we can reconstruct the path.

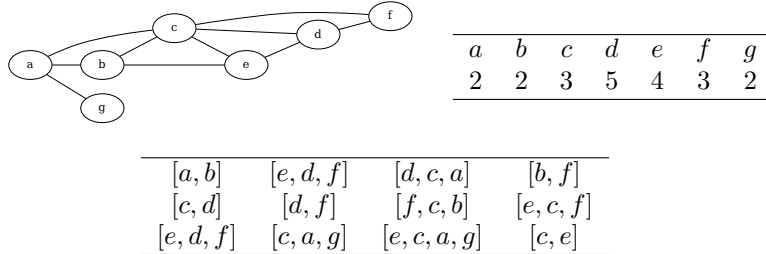


Figure 1: (up left) A road network. (up right) Capacity of each node. (down) Sample of vehicle routes (Shortest paths).

From a more practical point of view we want to implement our uniform sampler on standard libraries and run traffic simulations on real road networks using data from OpenStreetMap. Our aim would be to implement our sampler in Python and integrating it to NetworkX library [4]. Then, road network data from OpenStreetMap can be used through the interface OSMnx [2].

As a further step, the proposed approach could then be generalized to dynamic graphs using standard formalism such that link streams or temporal graphs [6].

Expected achievements:

- An academic paper submission containing a theoretical and experimental part on the sampling of geodesics in graphs.
- An open-source Python implementation of the sampler integrated to NetworkX library.

3 Positioning in regard to LIP6

Our project has its roots in the **”Architecture, Systems, and Network” (ASN)** axis where we study networks with a dynamic process on top of them namely the traffic. Obviously the desing and the analysis of algorithms is also associated to **”Theory and Mathematics of Computing” (TMC)** axis. The routes of vehicles are considered independently from each others and can therefore be seen as distributed agents on the network.

This project has the potential to interest a wide range of people in the LIP6 and more particularly researchers from ComplexNetworks, APR and NPA.

4 Internship

The project main funding will be dedicated to a Master’s thesis student that will work on the topic jointly with the supervisors of the project named on top of

this document. The student will do their master's thesis in either of the teams concerned with the project namely ComplexNetworks and APR. The title of their thesis will be the same as the title of this document.

References

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A Budget

The main aim of our project is to fund a **Master's thesis of 6 months** duration. Additionally, a funding of a **travel to a conference** where the student could present their work in venues such that GASCom, AlgoTel, ComplexNetworks or FRCCS. Finally, **the student could visit for a week an institute** France or a neighbouring country (such that Belgium or Germany) to present their research and gather more ideas around the subject.

Expected budget:

- 6 months internship (3600 euros).
- Conference participation (900 euros).
- Visit of an institute (1000 euros).

In total this would amount to 5500 euros.