Efficient Execution on GPUs of Field-based Vehicular Mobility Models

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Large-scale scenarios of vehicular traffic simulation problems are characterized by complex queuing effects, control mechanisms and other interactions of the traffic on the control and vice versa. While small-sized scenarios are relatively easy to explore and analyze, larger scenarios need specialized treatment for efficient execution. The simulation challenges of speed and scale become pronounced when network sizes are very large (millions of road intersections) and/or vehicular traffic load is immense (several million simultaneously active vehicles).

Commonly used execution approaches roughly correspond to the two extremes of the simulation spectrum. Aggregate models correspond to one extreme, typically employed to achieve coarse results at a relatively high simulation speed. Micro-simulation represents the other extreme, employed for finer granularity at the expense of greatly decreased simulation speed. Hybrid methods are emerging as *via media* that provide medium level modeling granularity while still affording fast execution. In some of our active projects in real-time data-driven simulations, we are developing one such hybrid method. Two novel aspects of our hybrid method are: (1) formulation of a field-based model of vehicular traffic movement in a large road network (2) fast execution of the field-based hybrid model on data-parallel platforms of general-purpose graphics processing units (GPUs).

In field-based formulation, the road network control is viewed as a spatially distributed field, (analogous to physical fields such as magnetic field) in which vehicles are immersed. These vehicles are influenced by the field and undergo corresponding movement. The field is defined in terms of vectors (directionality and intensity) of movement at each network node. A canonical regular vector field grid scheme is defined, to which any arbitrary road network can be mapped.

A distinguishing aspect of our field-based formulation, compared to prior field-based formulations, is the ability to include additional non-linear behavioral details such as queuing and randomized, directed flows. The consequent additional complexity in execution of such a generalized field-based model is addressed using a GPU-based execution approach.

In the GPU-based execution, the field-based model is executed with probabilistic transitions of vehicular counts between adjacent road network segments. States of the road network, along with detailed information on vehicular traffic loading, are carefully encoded to minimize memory requirements for representation and manipulation during simulation. Thereafter, execution is mapped using traditional GPU-based techniques for data-parallel execution.

An early version of our prototype implementation is currently operational. Preliminary results show scalability to a field of over 2 million network nodes, and 100 million represented vehicles. In evacuation simulations, for example, arbitrary fields can be defined to represent any evacuation control scheme. Execution speed is being compared with the extremes of aggregate and micro-simulation. Current speeds show that results from our hybrid model execution are achieved several fold faster than existing micro-simulation methods, while greatly increasing the ability to simulate larger networks, from tens of thousands of nodes of extant tools to millions of nodes in our new tool..