Region-based Urban Traffic Management

Abstract

Quality of life in cities, especially for vehicle owners, can be associated with the delay experienced by drivers, a direct consequence of congestion. Costs associated with delays incurred to travelers during peak periods include the loss of man-hours, increased vehicle emissions, increased fuel consumption and more. The magnitude of the socio-economic impact of congestion is so great, that the European Commission stated in a White Paper that the annual costs associated with congestion will accumulate to $102 billion in the European Community alone. According to Bloomberg, traffic congestion in the United States in 2009 costs the economy $114.8 billion. Unfortunately, due to limited space availability in modern urban regions, infrastructure upgrade and extension costs are prohibitive, with optimal utilization of available infrastructure being the only viable alternative. This work includes implementations of several modules of a proposed Region-based Urban Traffic Simulation and Management Framework, which takes advantage of the Urban-scale Macroscopic Fundamental Diagram concept. Concretely, weighted feature extensions of center-based clustering methods are introduced and compared with an implementation of normalized spectral clustering. The weighted k-harmonic means clustering outperforms all other methods when applied to an urban traffic network encapsulating Singapore's Central Business District, and can be used as part of the partitioning system module. The partitioning of the urban traffic network into homogeneously congested regions is an essential requirement for the existence and validity of Urban-scale Macroscopic Fundamental Diagram. Subsequently, as part of the macroscopic dynamics module, a multi-class extension of a regional dynamic traffic model, the Network Transmission Model, is introduced and subsequently used to simulate regional traffic dynamics. Two innovative region-based prescriptive route guidance approaches, as part of the centralized optimization module, are introduced, a non-predictive strategic learning-based routing method and a predictive simulation-based routing method. They are applied on a 16-region, diamond grid network which makes use of the Network Transmission Model to simulate the regional traffic dynamics. Their performance is compared to multinomial logit routing, a realistic reference case which models self-interested traveler route choice behavior. It should be noted that, all routing methods come integrated with a Public Transit Diversion mechanism. As expected, the predictive routing method outperforms all other routing methods. A market penetration scheme is introduced and three traveler classes are defined, the 1st traveler class making use of autonomous vehicles, the 2nd traveler class making use of conventional vehicles equipped with Route Guidance and Information System and the 3rd traveler class making use of unequipped conventional vehicles. The 1st class is represented by the predictive routing method with full compliance and under two information provision scenarios S1 (imperfect information), S2 (perfect information), that affect travel time prediction accuracy. The 2nd class is represented by the non-predictive routing method with the possibility of non-compliance. The 3rd class is represented by multinomial logit routing, modeling route choice under imperfect travel time perception. Regional traffic dynamics for simultaneous application of all aforementioned routing methods are simulated, for various combinations of traveler class market penetration rates and non-compliance rates. An analysis of overall network performance gains, as well as individual performance metric results was conducted for each market penetration rate combination with promising results regarding the potential impact autonomous vehicles will have on overall network performance, as well as the individual benefits provided to all other traveler classes.