Poster: A Capacity Planning Framework for Event Brokers in Intelligent Transportation Cyber Physical Systems

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ABSTRACT
Transportation engineering is a mature discipline of engineering that provides effective and efficient methods and tools for traffic modeling and capacity planning, however, these artifacts incur limitations in the context of intelligent transportation systems (ITS) because they seldom incorporate cyber issues in their design. Conversely, Computer Science provides many sophisticated solutions for resource management in the cyber world but often overlook physical issues inherent in ITS. Consequently, neither discipline prepares designers and planners to implement a fully functional ITS. Capacity planning solutions for ITS require solutions that can holistically integrate physical artifacts, such as traffic modeling, with cyber artifacts, such as solutions for real-time information dissemination over wireless networks. To address these challenges, this paper presents preliminary ideas on the design of a framework based on the principles of surrogate modeling wherein small-scale, micro-simulations of the ITS cyber-physical system are used to develop training points, which in turn are used to train a surrogate model. The surrogate model is subsequently used to make planning decisions for ITS.

Categories and Subject Descriptors
I.6.5 [**Computing Methodologies**]: Simulation and Modeling – *model development, analysis and validation,*
J.2 [**Computer Applications**]: Physical Sciences and Engineering.

General Terms
Algorithms, Design, Experimentation.

Keywords
Capacity planning, event dissemination, cyber-physical, modeling, design methodology, interdisciplinary.

1. INTRODUCTION
Intelligent Transportation Systems (ITS) are envisioned to address the numerous challenges faced by the transportation sector [7]. One category of solutions envisioned in ITS, pertains to the real-time and reliable delivery of traffic-related information to drivers both for safety-critical applications (such as blind spot warnings during lane changing) and for applications that improve driving experience and help the environment (such as notification of congestion and rerouting advise that can help to alleviate traffic congestion and lost productivity). The dissemination of information for these services is facilitated by brokers, such as road side units (RSUs) and even cellular towers. For the timely and scalable dissemination of information, there is a need for effective capacity planning for the RSUs or equivalent infrastructure.

Capacity planning for ITS is a hard problem because it must account for both the transportation-related challenges, *i.e.*, the physical dimension, and the information technology challenges, *i.e.*, the cyber dimension. Deploying real infrastructure elements and testing different hypotheses is unrealistic due to high capital costs. What is required is a design-time solution that can accurately model the ITS CPS, which in turn can help resolve the capacity planning challenges. However, for a design-time solution an approach based on detailed simulations is infeasible due to scalability issues arising from the computationally intensive properties of such simulations.

In this paper we present preliminary ideas on a framework that provides a way in which decisions regarding the system can be made quickly and inexpensively, moving the design of the cyber-physical system closer to its real-world goal. To address the problems with scalability of simulations, we rely on using a surrogate model, which is trained using a relatively small number of training points obtained from a small set of microsimulations. The chosen surrogate model is then used to make decisions regarding the system. We believe that the strength of this framework is that once the system is characterized using a surrogate model, subsequently the model can be used in both the planning stages (*e.g.*, infrastructure decisions like placement of the RSUs) and at runtime once the system is built (*e.g.*, for information dissemination such as how to reroute vehicles and when to send out the rerouting information). Our research is seeking to validate these claims.

2. RELATED RESEARCH
Since the inception of ITS, simulation has been used in order to envision potential implementations. Microsimulation in particular is suggested as the appropriate method for testing ITS, over both Highway Capacity Manual (HCM) procedures and macroscopic simulation in [3]. Both [3] and [1] provide suggestions on how best to build and validate realistic microscopic models for transportation systems. An actual ITS deployment is validated against microsimulation models in [5], although the system is for

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adaptive traffic control systems and not for information dissemination in vehicular adhoc networks (VANETs).

The use of optimization techniques for infrastructure deployment and system planning is also already in use within the field of ITS. There are various optimization statements and goals that are being utilized: maximizing coverage while guaranteeing a minimum amount of coverage time [9]; maximizing the reliability of information dissemination [8]; bandwidth minimization as well as travel-time minimization [6]; and maximizing the utility that comes from hardware distribution and information gathering [2].

Our research proposes extending current decision-making practices in ITS development and deployment to include surrogate models in order to characterize the system more efficiently than just microsimulation and optimization can do alone.

3. A METHODOLOGY AND FRAMEWORK FOR CAPACITY PLANNING IN ITS

Our proposed methodology shown in Figure 1 comprises the following four steps:

1. **Collecting training points** – A small number of microsimulations involving the CPS properties of ITS are conducted to collect training points needed to develop the surrogate models of ITS CPS.
2. **Building surrogate models** – the second step is to develop the surrogate models using the training points for the system under study. We use the Gaussian Process (GP) modeling approach [4].
3. **Validating the surrogate models** – once the surrogate models are developed, they must be validated for accuracy and correctness, which forms our third step.
4. **Optimizing the decisions** – once the models are validated, we use optimization techniques to make optimized engineering decisions.

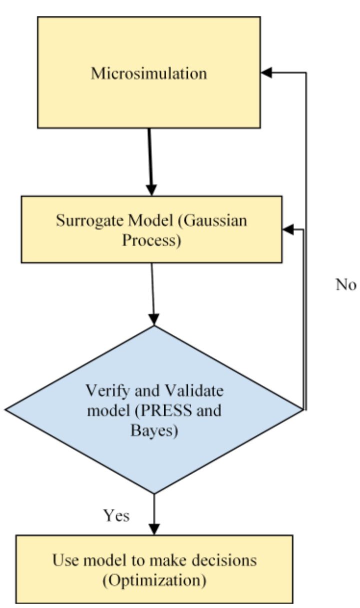

Figure 1. Methodology

Surrogate modeling provides an inexpensive but highly accurate design-time solution for designing complex systems. We believe that such a methodology has not been exploited in ITS, which illustrate complex event processing and event dissemination properties.

The proposed methodology has thus far been applied by using a simulation involving one vehicle passing an RSU. The speed of the vehicle and power of the RSU beacon are varied as inputs and the communication window is measured as an output. Training points are used in order to train a GP model. The model is verified and used in order to create a Pareto front that demonstrates the speed and power trade off inherent in this physical system.

In the future, this methodology will be applied to more complex, realistic systems. The ability to model such complex systems using a surrogate model will make it feasible to examine the full range of trade-offs prior to deployment (in the design phase) and will greatly increase the likelihood of being able to make run-time decisions during the ITS deployment.

4. ACKNOWLEDGMENTS

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