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Extended Kalman Filter for the On-line Calibration of Traffic Simulation Models

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The main purpose of this research was to develop methods and procedures for using the on-line data collected by field traffic detectors in the calibration of simulation models, whether they are to be used for off-line analyses or on-line traffic state estimation. Initially, the study's goal was to use an Extended Kalman Filter to achieve this objective. Later however, we decided to use an Artificial Neural Network (ANN) to act as a post-processing algorithm that would bring the simulation model's predictions closer to real-world observations.

For the experimental setup of the study, a segment of Interstate I-89 passing through the Burlington Metropolitan area in Northwestern Vermont was selected. The segment was then modeled using two different traffic simulation models. One model was developed using the PARAllel MICroscopic Simulation (PARAMICS) model, a suite of microscopic traffic simulation software for modeling freeway and arterial networks developed by Quadstone, Limited. The PARAMICS model, in this study, was used to represent reality. The second model was developed using the "Cell Transmission Model" (CTM) developed by Daganzo at the University of California, Berkeley.

For off-line calibration, four CTM's parameters were selected to be manipulated, based on the sensitivity of the model to each of the parameters. The four selected parameters were: (1) the free flow speed; (2) the backward wave speed; (3) accident severity, which is a value between 0 and 1 representing the reduction in roadway capacity as a result of an accident; and (4) the jam density modifier, a value between 0 and 1 used to account for the space between vehicles during jam conditions. A quasi-exhaustive search procedure was then used to determine the values of the Cell-Transmission Model's parameters that would best calibrate that model to the PARAMICS model. The results indicated that the accident-free behavior, primarily linearly dependant on a function of free-flow speed, was successfully calibrated using the exhaustive search procedure. However, the spikes in travel time resulting from capacity reducing accidents, primarily dependant on a complex non-linear relationship between multiple variables, were not as successfully calibrated.

For on-line applications, the study then developed an ANN model for use as a post-processing algorithm to adjust the Cell-Transmission Model's estimates in order to bring them closer to PARAMICS, than with the off-line calibration procedure alone. The abilities of the Multi-Layer Percepton (MLP) and Jordan/Elman topologies implemented as post-exhaustive search algorithms to further refine and adjust the Cell-Transmission Model's results were investigated and compared. For both ANN topologies, the input data set was comprised of three variables: the Cell-Transmission Model's resulting travel time after the exhaustive search procedure and information about accident location and duration. The target data set, used for ANN training, was the travel time produced by the PARAMICS model.

The MLP topology was constructed from one hidden layer with 12 nodes that used a hyperbolic tangent transfer function. Gradient decent with momentum was used as the back-propagation algorithm. For the Jordan/Elman network, preliminary experimentation revealed that an effective network could be constructed from 2 hidden layers with 8 and 4 nodes respectively that also used a hyperbolic tangent transfer function. A conjugant-gradient descent method was used for the back-propagation algorithm. As mentioned above, for both topologies, the input layer consisted of 3 nodes, one corresponding to each of the following: (1) the travel time after the exhaustive search: (2) accident location; and (3) accident duration. Both network topologies incorporated cross validation into the training algorithm to prevent over training the network.

Evaluations results tended to indicate that a MLP ANN implemented as a post-exhaustive search algorithm is capable of improving the calibration of the Cell-Transmission Model to the PARAMICS model. The average absolute percent error for the MLP ANN was 5.1%, as compared to the 9.2% average absolute percent error incurred by the exhaustive search alone. The improvement in calibration is most drastic in the fitting of spikes in travel time caused by capacity reducing incidents.