

SIMULATION BASED TRAFFIC INFORMATION SYSTEM

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SUMMARY

There is a growing need for improvement in the efficiency of urban traffic in order to ensure the sustainability of modern cities. It is now recognized that this can be achieved through the coordinated improvement of traffic monitoring and management schemes in traffic control centers and the provision of information services for ordinary road users. The real-time (on-line) simulation can have an important role in these schemes. In this paper the concept of microscopic on-line traffic simulation is presented together with potential applications. As an application real-time traffic information service through Internet is presented. Also the use of on-line simulation for traffic control purposes is discussed. A prototype system is demonstrated based on HUTSIM urban traffic simulator, DIME distributed memory server and SCOOT- urban traffic control system. The presented methodology can be applied to other UTC-systems if proper real-time data is available.

ON-LINE SIMULATION

Usually simulation models are used disconnected from the actual traffic system (off-line simulation). A large number of field measurements are needed in order to calibrate and validate the model properly. An alternative approach is to receive measurements continuously and let the simulator adapt itself to fit the measurements. Here this method is called on-line simulation or real-time simulation since the simulation must be synchronized with real time.

The on-line simulation can be used for monitoring the overall status of the traffic system despite of the incomplete detector input. The basic data obtained through the detector system is the lane-occupancy data from detectors that are usually embedded in the road surface. Each detector provides information about the presence or absence of a vehicle in a discrete location. The rest of the information about traffic situation must be derived from the general knowledge of system layout, statistics of the traffic patterns and the estimate of vehicle dynamics. In on-line simulation all these factors are methodically combined with the detector input.

In the absence of the actual traffic data from the detectors, simulation model generates vehicles on a statistical basis. Ideally this should be accurate enough to produce reliable average measures i.e. in off-line simulation mode. However, in real-time operation average measures are not always relevant, so the micro-simulation model is made realistic by replacing the time headway

distribution with real-time arrivals. Since the simulation model is to mirror the operation of the actual traffic control system it requires also the real-time signal status data.

The real-time simulation approach postulated here extends significantly the monitoring capabilities of telemetry systems by extrapolating the traffic occurrences in discrete locations through the simulation of realistic traffic flows in the whole network. The motivation for such a system is to provide a more complete basis for traffic management and information systems with simulated traffic indicators. From the detailed microsimulation model all kinds of higher order measures can be computed and used to indicate the traffic fluency, emissions or safety. These comprehensive indicators can be used for real-time traffic information systems to help road users or as an input for traffic management and control systems.

The simulation model provides also an engine for creating hypothetical traffic situations. Therefore it is possible to provide short term traffic forecasting by running an additional on-line simulation faster than actual time. This predictive simulation model needs its starting point as input from the real-time model (6).

USING THE REAL-TIME DATA

To facilitate the on-line simulation, the detector data must be received and processed. Therefore the simulation system must be supplemented with an additional functionality called state estimation. The state estimation reads the detector data and takes necessary actions on the simulation model to maintain consistency between simulated and measured traffic. The solid basis for the successful state estimation is a good off-line simulation model that defines the layout, statistics and vehicle dynamics of the simulated traffic system. In on-line simulation some of the distributions can be replaced by actual real-time data, when available from detectors. The accuracy of on-line simulation depends on the amount and quality of the detector input data.

Most of all detector data is needed at the boundary links of the simulation model. These detectors are used to feed traffic into the model. These input detectors provide more realistic traffic input by replacing the time headway distributions with real-time data. In a microscopic simulation model individual vehicles need to be recognized and generated respectively. The vehicle arrivals can be detected from the edges of the detector signal i.e. the signal goes from passive to active or vice versa. This method is not completely reliable if the detector covers more than one lane.

With a single loop detector only the arrival time of the vehicle is obtained. The speed, length and vehicle type are difficult to obtain without special detector or detector pair. A pair of loops in each boundary link would remarkably improve the quality of input data for the on-line simulation allowing replacement of speed- and vehicle type distributions with real-time data.

Ideally vehicles need to be generated on boundary links only. The traffic on internal links should appear as a consequence of the input traffic. In practice the traffic on internal links needs to be corrected according to the detector data. If the detector data shows more traffic than simulated then additional vehicles must be generated. Conversely vehicles need to be removed if measured traffic is more than the simulated one.

Usually the turning direction of vehicles is not known in advance. Therefore the turning movements must be randomized at every intersection. In order to distribute the traffic correctly

the turning movement distributions must be kept up to date according to the detector counts. Because of the random fluctuations, even the correct turning movement distributions do not guarantee correct traffic volumes in internal links and therefore some vehicles must be added/removed at measurement points.

If additional detector data is available it can be used for improve the simulation accuracy. For example a detector in front of the stop line can be used to indicate when the queue is completely discharged. A detector after stop line can be used to adjust discharge flow parameters. Generally the model should be developed to be self adjusting, so that it continuously adapts its essential parameters to match with the detector occupancies. In near future complementary traffic data can be obtained from other sources like GPS or automatic video image processing. This will help even more in adjusting the simulation parameters properly and dynamically.

PROTOTYPE SYSTEM AND CASE STUDY

A prototype of the proposed real-time simulation principle was constructed in co-operation of Helsinki University of Technology (HUT) and the Nottingham Trent University (NTU). The prototype system is based on the HUTSIM microscopic traffic simulator (5), the SCOOT-urban traffic control system, and a shared memory communication framework called DIME (DIstributed shared Memory Environment) (1). In the distributed framework number of client systems (HUTSIM, SCOOT etc.) can be communicating with each other through a shared memory server (3).

The SCOOT-system is an adaptive urban traffic control system that optimizes the split, cycle, and offset times of the traffic signals. The SCOOT-optimization is based on maintaining a macroscopic simulation model of the traffic flows. The system provides on-line detector data and signal data as well as measurements of the traffic model, which make it most suitable for on-line applications.

The collaboration between the Nottingham Trent University and the Nottingham Traffic Control Center has resulted in the development of a software environment that enables efficient access to the real time traffic data supplied by the SCOOT-system (2). The DIME (Distributed Memory Environment) system allows various distributed applications to communicate with each other through the LAN or WAN networks while maintaining the shared memory logical view of data. The communication harness is based on the TCP/IP-protocol and client/server architecture and it is independent of the physical network type.

The DIME-system offers the communication framework needed for passing messages between the processes. Each process connects to a shared memory manager which can be running under UNIX or on a PC. The memory manager is acting as a server to which multiple clients can connect. Basically each client can both read and write data of several areas (buffers) of the memory manager.

One of the clients connected to the memory manager is the SCOOT-system. Two types of messages are received from SCOOT. The M19-messages supply the detector status data with a resolution of 0.25 seconds. The M14 message supplies the link and signal data with one second time resolution.

Both the M19 and M14 buffers of the memory manager are read by a message interpreter client, which converts them into HUTSIM message format to generate vehicles and to control signal status. A third type of client process reads the M14 messages and estimates the turning movement percentages. It sends new turning movement distributions to HUTSIM every 15 minutes.

The fourth client of the system is the simulation program itself. HUTSIM is basically operating normally and running at the speed of actual time. HUTSIM processes the external events provided by the shared memory server. The present implementation involves three types of messages namely the vehicle arrival, signal status change and turning distribution messages.

Since there is a variable communication delay between SCOOT and HUTSIM clients, it is not possible to run the simulation in exactly real-time, but delayed with constant value typically 5-15 seconds.

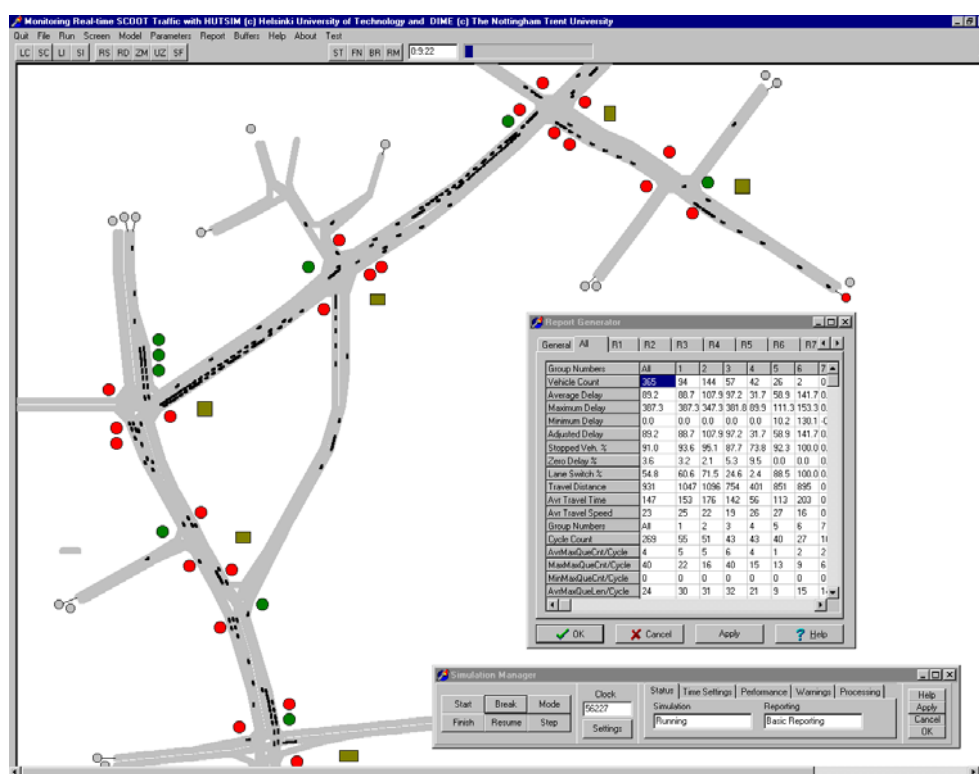


Figure 1. Real-time simulation of Mansfield test area with HUTSIM/DIME.

The system was demonstrated by simulation of Mansfield test area. This test area covers six intersections in the center of Mansfield. The rush hour traffic in this area is very congested. A detailed HUTSIM-model was constructed (figure 1) including the layout, lane organization, detector positions, etc. The traffic was fed according to the detector data in boundary links. In internal links the turning movement percentages were adjusted according to the detector data.

The functioning of the system was verified by comparing the queue outputs of SCOOT (that were verified against field measurements) with the queue length in HUTSIM. The results were generally good (figure 2). The results indicated that it is not sufficient to use turning percentages only (in internal links), but additionally vehicles have to be generated or removed to avoid cumulation of small errors a over long period of time.

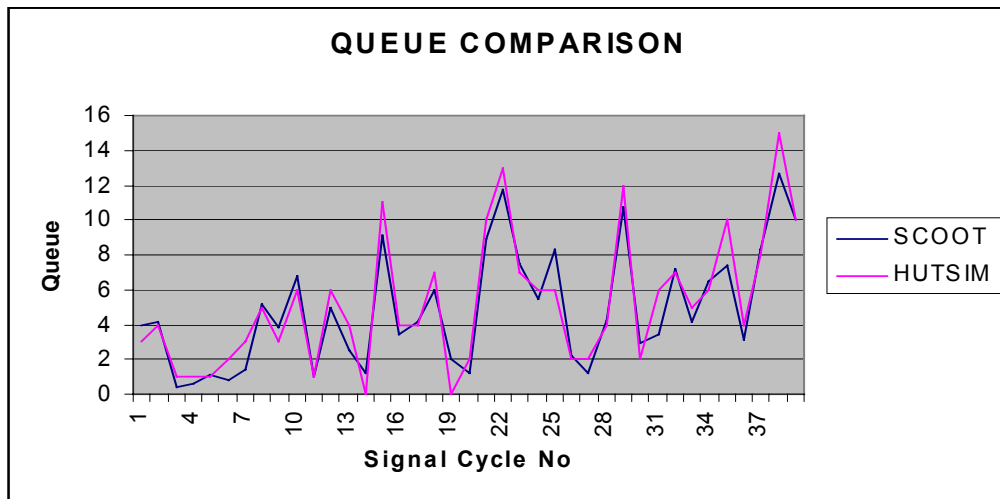


Figure 2. Verifying the operation of HUTSIM on-line simulation with SCOOT.

PROVIDING TRAFFIC INFORMATION AND MANAGEMENT SERVICES

The real-time simulation provides a basis for a variety of traffic information services (4). Once the simulation is reliably running all kinds of higher order measures can be derived from it. These measures may involve the classic indicators of performance (travel times, delays, queues, and stops) as well as indicators of emissions, safety, and control status. The simulation also provides live visualization of the traffic situations.

The simulation system as such can be used by any party having the simulation program and Internet connection. The most potential users are organizations involved in maintaining the traffic system. The traffic management and control centers are the most likely users, but also traffic planning, maintenance, and research organizations can benefit from the system. The police, emergency services, transport companies, and local radio stations have also their special interest in knowing the traffic conditions in real-time.

For public information services the on-line simulation as such is not very practical because special simulation software is needed. The publication through Internet provides a more suitable channel for a large scale distribution of the traffic information. Through a WWW-service anyone with a web-browser can have access to the real-time traffic information. This kind of distribution can also be made to support various types of terminal devices like desktop, portable, and palmtop computers as well as mobile phones. The improved delivery of the real-time traffic information is likely to affect the distribution of traffic demand and therefore reduce traffic problems.

Different types of simulation models can be integrated and utilized in a traffic information system like demonstrated in *figure 3*. The prerequisite is the availability of real-time detector and control data supplied here by the SCOOT-system (7). Here HUTSIM provides a microscopic view of the prevailing traffic situations. It is also possible to use simulation model for short term predictions as has been tested with macroscopic simulation model. The PADSIM simulator was used to predict the development of queue lengths over next 20 minutes (6).

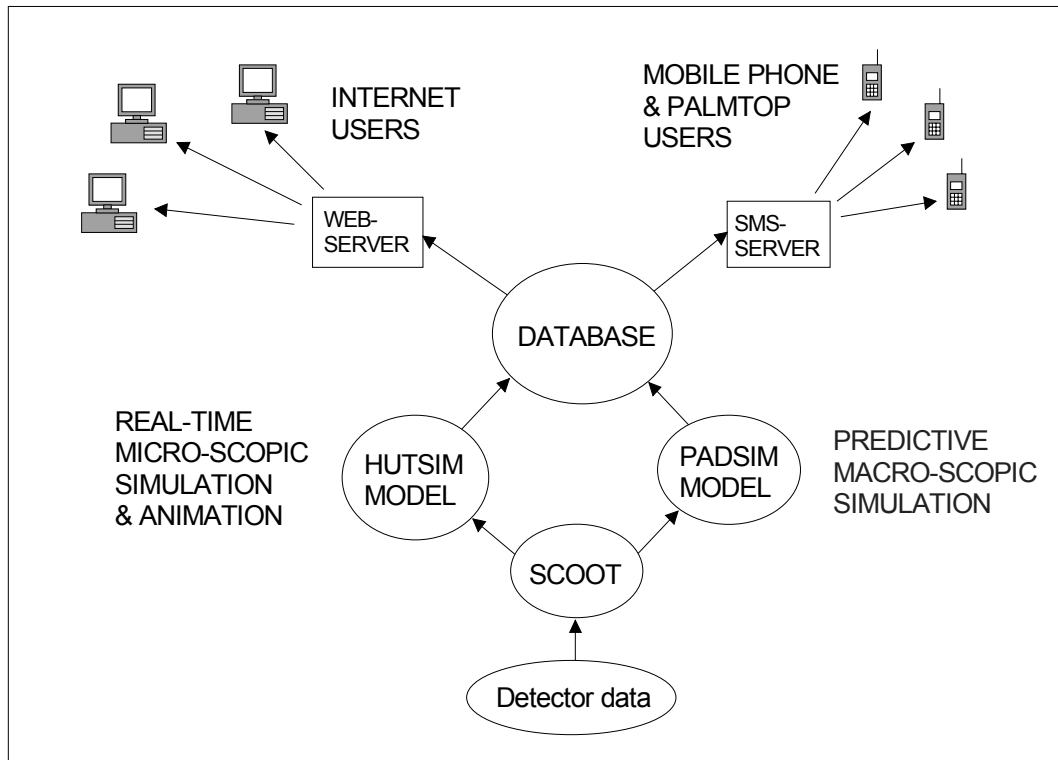


Figure 3. Integrating simulation models with traffic information services.

It is also possible to utilize the on-line simulation for traffic management and control purposes. The simulation output provides a comprehensive database that can be used as input to any type of traffic control agents. With the real-time traffic model the control agents have unlimited access to all measures of the traffic system. This makes it possible to develop any type of new control schemes based on any measures of the traffic including fluency, safety, economical and environmental aspects. Advanced control algorithms require higher level inputs that can be derived from the on-line simulation model.

The simulation based traffic control and management principle can be outlined as several layers shown in *figure 4*. The on-line traffic simulation model runs in real time on layer two. The detector data received by layer one is used to generate traffic and to maintain consistency between simulated and measured traffic. Layer three has unlimited access to the simulated traffic and hence is able to provide any type of measures and indicators of the traffic situations. The control algorithms on layer four perform the actual control decisions on given premises. Basically the decisions can be based on any type of algorithms. The decision output is delivered to the control engines that adapts its operation respectively (layer five). Finally the signal control output is duplicated to the field operation and back to the simulation model. The same concept is applicable to any type of dynamic traffic control like VMS-control and route guidance. The *figure 4* also illustrates that if the simulated measurements were directed for traffic information purposes (layer six), then they will affect only the traffic demand while control and guidance operations affect the actual traffic process.

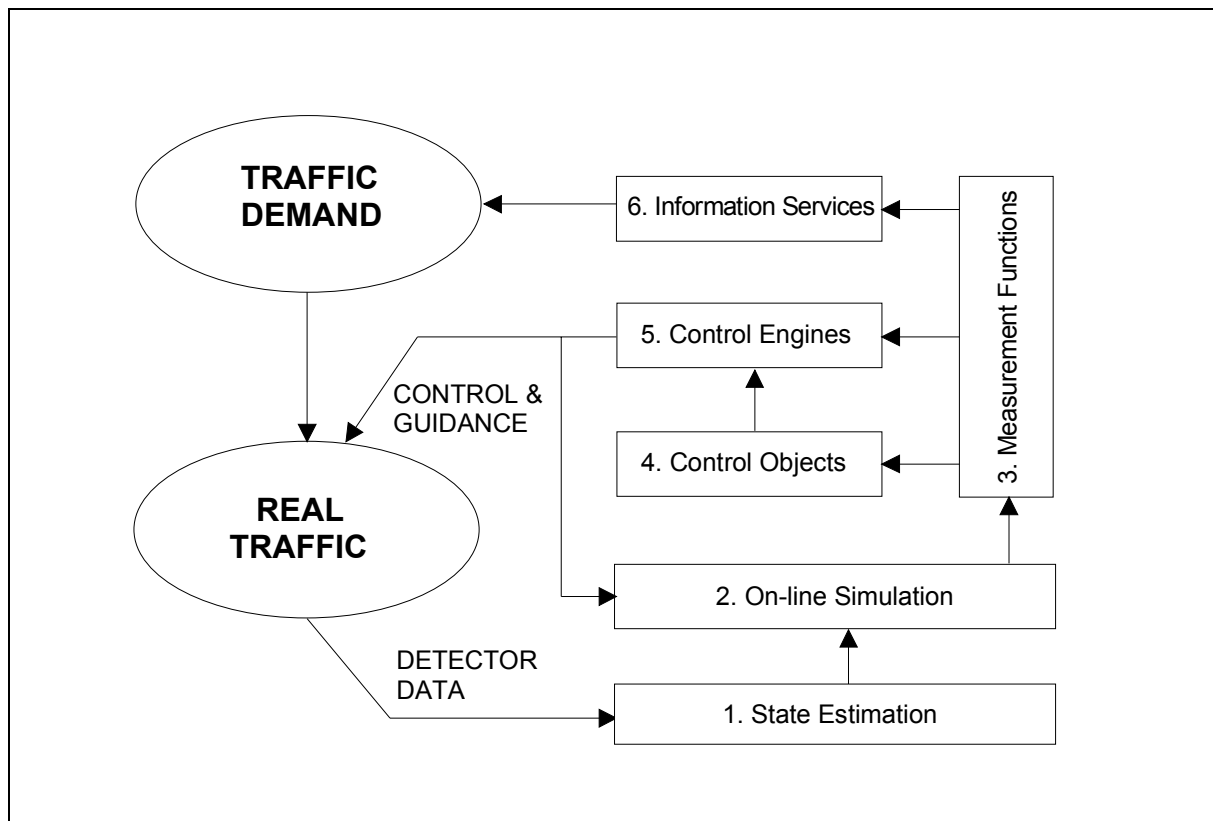


Figure 4. Simulation based traffic information and control.

CONCLUSIONS

The microscopic on-line simulation seems to offer a solid basis for traffic information and monitoring purposes. It provides all type of numerical indicators as well as live animation. The accuracy of the presented on-line simulation is satisfactory if each link entry has detectors. Simulation as such can be used for monitoring in traffic control centers, but for general public distribution through Internet or mobile phones is desirable. The on-line simulation model also provides a comprehensive database for traffic control and management applications.

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