Including ITS in Microsimulation models

Pete Sykes SIAS Ltd., Dave Bennett, SIAS Ltd.

Abstract— **Paramics, a transport planning microsimulation package has been extended to include an Advanced Control Interface based on SNMP – Simple Network Management Protocol. The interface enables the inclusion of external ITS control devices within a traffic simulation. This paper describes the interface and the test scenarios to which it has been applied.**

I. INTRODUCTION

SIAS Paramics[1] is a PC-based road traffic microsimulation software system. It simulates the individual components of traffic flow and congestion, and presents its output as a real-time visual display for traffic management and road network design. It has been under development for more than a decade by SIAS. In addition to the inclusion of the detailed physical description of the road network, features such as bus operations and traffic signal settings, driver behavioural characteristics and vehicle kinematics are modelled. This provides an accurate representation of the variable circumstances which lead to congestion in all types of road network. SIAS Paramics is well established as a reliable microsimulation system suitable for application to all road transport planning problems in situations from a single junction analysis to large strategic models.

To date, time varying control systems have been accommodated by splitting a microsimulation model into different time periods and changing key characteristics of the model for each. For example, a variable speed restriction would be modelled by adjusting link speed at specific times, but with no account taken of the behaviour of the traffic in the network at the time.

The introduction of the Paramics Advanced control Interface based on SNMP now allows modellers to relay instructions and advice to simulated vehicles based on the observed traffic conditions in the simulation.

This paper describes the Paramics interface for signal and ITS control, and provides three test examples of its deployment.

II. PARAMICS ADVANCED CONTROL INTERFACE

The five components of the interface are shown in Fig 1.

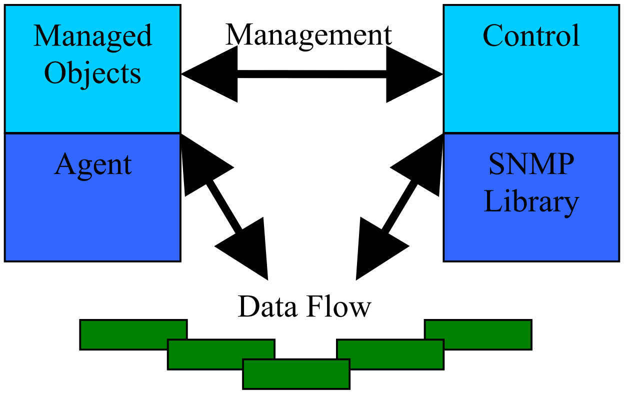

Fig. 1. The software components of the Paramics Advanced Control Interface.

1) *Managed Objects*

In SNMP terminology, “managed objects” are devices programmed into the simulation by the transport modeller to act as road traffic detectors (eg inductive loops) or implement traffic control. (e.g. variable message signs)

2) *The SNMP Agent*

The software module within Paramics that communicates with the controller.

3) *The Network*

This can be any IP network – eg. office intranet, internet.

4) *The SNMP library*

This may be composed of generic SNMP routines, or an ActiveX control specific to this interface which raises the level of abstraction of the interface to be very close to the managed objects in the Paramics simulation. This can be used by general office applications software, or from programming languages such as Visual Basic.

5) *The Controller.*

The software which implements the ITS system.

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Pete Sykes is an Associate of SIAS Ltd., a transport planning consultancy based in Edinburgh, Scotland. He was responsible for the first prototype of Paramics in 1987 (e-mail Pete.Sykes@sias.com).

Dave Bennett is a programmer working on Paramics (e-mail Dave.Bennett@sias.com).

III. THE PARAMICS MANAGEMENT INFORMATION BASE (MIB)

SNMP, [2] a well established protocol in the area of computer systems management, was chosen as the low level protocol for its simplicity. SNMP consists of three types of operations, "get " and "set " which exchange data, and "trap" which informs the controller about events in the simulation. SNMP operates on network*s* and is effectively platform independent, so a controller running on one computer platform may communicate with a simulation on another. It is designed for the management of remote devices, a task similar in road networks and computer networks. SNMP is a well defined protocol, with readily available software and expertise.

The Paramics MIB follows the conventional SNMP structure of columnar objects, organised in conceptual tables using an indexing system shared between tables in the same group. The groups are:

1) Control

Provides data on the version of the Paramics software, the host computer, the simulation model identifier, and the current status of the model.

2) Event Notification and Alarms

Used to send unsolicited SNMP messages (i.e. traps). These warn the controller when the simulation starts, stops, reaches a particular time, is edited or reloaded. Alarms allow controllers to instruct Paramics to monitor specific object values, and send a message if a value crosses a threshold.

3) Buses and Bus Routes

The buses table provides information on the position, speed, last bus stop, and passenger load of each bus currently active in the bus routes table. It mimics a GPS-instrumented public service vehicle which can be polled to discover its current activity.

4) Loop Detectors

The detectors table and its associated sub-tables provide detailed access to the statistics associated with loop detectors within the simulation. The data tables provide a lane by lane account of the statistics, including the vehicle count, the headway between vehicles, and the occupancy of the detector. The latter is presented as a simple flag, a moving average, or as a bitmap of loop occupancy as required by some UTC systems. [3] Vehicle turn counts and messages from instrumented vehicles can be retrieved from these loops.

5) Signalised Nodes

Control and timing tables provide information and control over signalised nodes within a model. The control table provides the information on the current state of the signals, i.e. the current stage, the time left for it to run, and next stage. Note that the latter variable may be 'set' by the controller to provide the ability to implement hurry calls and alter stage ordering. The timing table allows the controller to change stage times.

6) Flow Controlled Nodes

This set of tables provide a mechanism for taking direct control over the priorities and light states of each turn at specific nodes within the model. These nodes have no preset signal stages, their traffic movements are directly controlled via SNMP by setting signal states and movement priorities. This system is used to link to signal control systems such as CCOL[4] where there is no predefined set of stages or sequence of actions.

7) ITS Control Devices

These are active control devices in the simulation such as VMS, radio broadcasts or in-car information systems. The use of these devices is the focus of this paper and is described in more detail later.

8) ITS detectors

More sophisticated detector devices are incorporated into the simulation and made available to the controller via SNMP. For example, the individual vehicle journey time statistic along a specified route is available via SNMP as a proxy for Automatic Number Plate Recognition (ANPR), which produces a similar journey time measure. Similarly, queue length detection and pollution monitors make their data available to the controller. Car park occupancy may also be monitored.

IV. CONTROL DEVICES

The ITS control devices are the core of the system. Examples of these are VMS, wireless broadcasts or in-car information systems. These devices may take a variety of forms, and their messages may be direct or abstract, and their response rate can be influenced by many factors. Hence their implementation within the simulation has been made generic, with the tasks of interpreting messages and deriving response rates assigned to the controller.

Control devices are implemented within Paramics with three major sets of attributes:

1) Physical Attributes

These concern physical appearance within the model. For example, a roadside sign is represented by a DXF model defined by location and appearance, whereas a radio broadcast may have no meaningful form or location. The control device also has a sphere of influence defined in terms of a set of links, the distance travelled from the device, a radius of operation, or simply the entire network.

A label may be attached to the device, which is intended to show the message as given to drivers. This is displayed in the DXF model in a set of polygons identified by a layer label. Note that this is intended for display only, and no attempt is made to parse the message in the simulation.

2) Behavioural Attributes

The message displayed in the physical attributes is interpreted for the simulated driver and is presented here as a formal set of actions rather than the natural language text assigned to the physical attributes. For example, a general VMS message "In Town Slow down" is frequently seen in Scotland and may be interpreted as resulting in a reduction in drivers' aggression. Similarly the message "Road-works at Junction 19 – expect delays" may be interpreted as a requirement for additional time to routes passing through a particular location.

Making this distinction between the physical message and its formal interpretation removes the problem of one message attempting to serve the multiple functions of visualisation and behavioural instruction in the simulation.

Behavioural modifications consist of:

- *Speed limit*: Modify the advisory speed limit, used to establish individual vehicle target speeds.
- *Lane restrictions*: Exclude certain vehicle types.
- *Aggression & Awareness*: Multi functional modifiers of vehicle behaviour.
- *Headway*: The mean time between following vehicles. This is also modified by the aggression level.
- *Delay* : The expected speed of a set of links. Note, this is not a new speed limit, but advice used for the calculation of routes.
- *Diversion*: Force vehicles to route through a specified waypoint.
- *Carpark*: Modify the destination car park.

Vehicle behaviour modifications in the simulation model are implemented in the SNMP MIB through a set of enumerated data types. Each ITS controller may influence several behaviours.

3) Response profile

The response profile specifies which drivers will act on the advice and its derivation is a function of the external control software. For example, an advisory speed limit may not achieve a high response rate, but a speed limit backed by a media safety campaign and visible enforcement is more likely to be adhered to. The simulation model cannot determine this, therefore the traffic modeller is required to contextualise the operation of each ITS controller.

Response rates may be specified by vehicle type, by awareness or aggression level, or by random sample, and each behaviour may have its own response profile.

V. WAYPOINTS

To complete the range of controls required to simulate contemporary ITS systems, a second level of route finding has been added to Paramics. The single level model undertakes dynamic assignment by calculating a cost to a destination from every link. A driver approaching a junction will take the calculated costs for each exit link, which for "familiar" drivers will include congestion delays, and apply a perturbation factor before selecting the lowest cost link.

Experience in building microsimulation models and an understanding of real driver behaviour suggests that such a simple route finding model is not adequate for long journeys with a lot of route choice. Waypoints have been introduced as a result.

A long journey may be delineated by a set of waypoints, the trip between each being treated as a short journey in its own right. On long journeys, drivers' routeing decisions are based on the best route to the next waypoint, ie. to the start of the next stage of the journey. Waypoints form a macro level network, while the components of the journey between them remain at the micro level.

The waypoint mechanism provides an ideal means of importing route information to the simulation by identifying locations where this information is to be applied. A simulated driver compiling a route through a macro-level network determines the costs of travelling between waypoints in the conventional way, ie. from distance and predicted time, or from previous knowledge. A modification to that cost may be advised by ITS, which may cause a driver to subsequently divert.

The combination of ITS and waypoints provides a flexible mechanism for response to route advice in the microsimulation model. For example, a VMS message "Long Queues at Junction 1" may be interpreted by drivers as "10% assume a 10 minute delay, 10% assume a 20 minute delay, and 80% didn't respond", with consequential re-routeing taking place.

VI. EXAMPLES OF ITS SIMULATION

SIAS's use of the Paramics ITS capability is evolving, and several systems have now been implemented [6]. A model of an ALINEA ramp meter signal controller in Glasgow [5] has been completed and satisfactorily calibrated. Here the controller algorithms were in the public domain and straightforward to reproduce, but elsewhere the algorithms are not available. This results in links to SCOOT, CCOL and SCATS being implemented as middleware, to provide for communications to external black box UTC systems and signal controllers.

A. MIDAS

The MIDAS (Motorway Incident Detection and Automatic Signalling) system [7] monitors traffic conditions on motorways by polling lane/loop occupancy to determine queue formation, and imposes mandatory speed restrictions by VMS. The system has been replicated as an ITS controller linked to the Paramics simulation.

Traffic flow information data is measured at sites 500m apart, consisting of two detector loops and a VMS gantry. When a queue is detected at a site, gantries up and down stream are set to display messages and speed limits intended to slow the approaching and merging traffic in a manner designed to prevent flow breakdown and reduce queues.

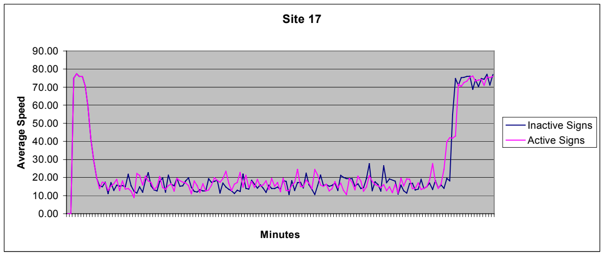

Fig 2 Queuing at the point where the incident is caused

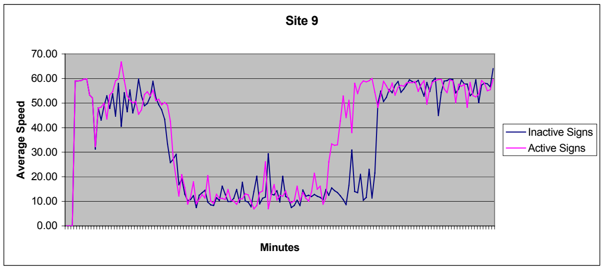

Fig. 3. Queuing 4km from he point where the incident is caused

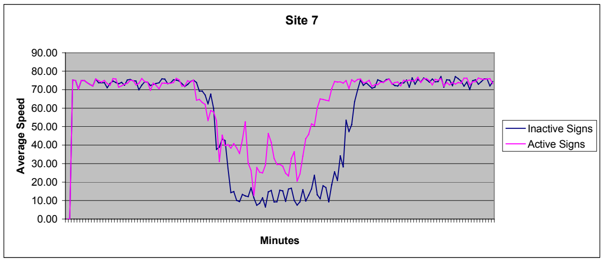

Fig 4. Queuing 5km from the point where the incident is caused

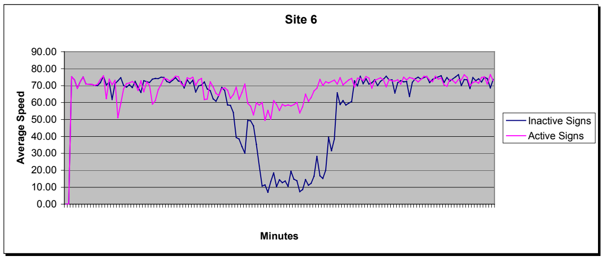

Fig5 . Queuing 5.5km from the point where the incident is caused

A MIDAS test was undertaken in a model of the Edinburgh City Bypass, a two-lane dual carriageway with an average daytime flow of 3000 vehicle per hour. The Paramics model covers 12 km and 9 junctions. An incident was created by artificially slowing a vehicle in both lanes. The resulting queue was monitored at the simulated loops, and the gantries displayed speed limits and queue warnings appropriate to their distance from the queue. 100% observance of the speed limit was assumed. The graphs for a 2½ hour simulation in Figs 2 to 5 show measured speed vs time of day.

Fig 2. Shows that at the point where the queue starts no change is observed to vehicle speeds on activating the signs. At this point vehicles are too close to the obstruction for the speed limit to have an effect. In Fig 3, 4km upstream of the incident, the queue can be seen to dissipate earlier, while at 5km back (Fig 4) the flow breaks down, but speeds do not drop to the same extent. Fig 5 demonstrates that 5.5 km from the source of the problem the queue is prevented from forming and answers the drivers conundrum- "I obeyed the warning signs about the queue, but there was no queue. Why?"

The MIDAS controller software was written in a one week exercise during which an experienced transport planner with a software engineer to learn how to use the Paramics Advanced Control Interface. The speed of production emphasised the ease of use of the interface.

B. *Poole Lifting Bridge*

Poole is a town in Dorset, England. The Blackwater Channel runs to the west of the town and is crossed by a lifting bridge which raises for shipping. There is a proposal for a second bridge [8] with a route information sign to be positioned at the point where drivers choose which bridge to use, dependent on the position of ships in the channel.

A small Paramics model was built to demonstrate that a VMS directed diversion could be modelled. The three instructions sent by the controller to the simulation are, (1) to display a message on the sign, in this case "Use East (or West) Bridge", (2) to force vehicles to divert to one or the other bridge waypoint, and (3), an assumed response rate (100%).

The controller software was written in Visual Basic and detects when a ship approaches the bridges, simulated by Paramics as a special vehicle on a dedicated route. It then uses the macro-route waypoint mechanism to communicate with the VMS sign.

The controller contains just 110 lines of active code to connect to the simulation, communicate with the ship detectors and message sign, operate the traffic signals at the bridges, and finally implement a simple algorithm to select the route. It was written in one day, and although using simplified algorithms hard-coded to a specific case, the exercise is a useful demonstration of ITS simulation in action.

C. *Car park study*

In many situations a journey will end in a carpark close to the final destination. However if this is full, vehicles must select and queue for another. Paramics can simulate this effect by preventing vehicles entering a carpark when it is full. It changes the destination carpark after a predetermined queueing time at the current carpark has elapsed. The new carpark destination is selected by consideration of the drive time to another carpark and the resulting walk time to the ultimate destination for the journey. This simulates the circulating behaviour of drivers searching for a parking space in a city centre.

The re-routing may be initiated as drivers queue at a carpark, or by using an ITS control device. In this case drivers may be advised of the status of the carparks at a remote location, or by a radio broadcast, at which point they may change their carpark destination, thus reducing the need to circulate.

Several ITS car park studies are under way in the UK, and it is anticipated that data on tolerance to queueing will be soon made available.

VII. CONCLUSION

The Advanced Control Interface, based on SNMP has shown that testing of ITS control algorithms within a microsimulation model can be moved from the domain of software engineers to software users, transport modellers.

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