SITS – Simulator of Intelligent Transportation Systems

Lino **Figueiredo**
Dept. of Electrical Engineering, ISEP-Institute of Engineering of Porto
Rua Dr. António Bernardino de Almeida
4200-072 Porto, Portugal
email: lbf@isep.ipp.pt

and

J. A. Tenreiro **Machado**
Dept. of Electrical Engineering, ISEP-Institute of Engineering of Porto
Rua Dr. António Bernardino de Almeida
4200-072 Porto, Portugal
email: jtm@isep.ipp.pt

ABSTRACT

This paper presents the most recent developments of the Simulator of Intelligent Transportation Systems (SITS). The SITS is based on a microscopic simulation approach to reproduce real traffic conditions in an urban or non-urban network. The program provides a detailed modelling of the traffic network, distinguishing between different types of vehicles and drivers and considering a wide range of network geometries. In order to analyze the quality of the microscopic traffic simulator SITS a benchmark test was performed.

1 INTRODUCTION

Intelligent Transportation Systems (ITS) is a global phenomenon, attracting worldwide interest from transportation professionals, automotive industry and political decision makers. ITS applies advanced communication, information and electronics technology to solve transportation problems such as, traffic congestion, safety, transport efficiency and environmental conservation [1].
One important research area is the simulation and modelling. Through these tools we can identify, quantify and analyse the phenomena revealed by an ITS deployment proposal. With mathematical models, one can simulate real-life situations, opening the possibility for the analysis that was only available through real systems. Therefore, we have the ability to create, evaluate and modify designs without the need to actually implement them. To resume one can say that in the ITS context, simulation models can be very attractive, as many of the products and services intended for deployment are relatively new and we need a detailed understanding of the likely impacts and effects. In the recent years have been developed simulation models to support the analysis in almost all the areas of ITS.

2 THE SITS SIMULATION PACKAGE

SITS is a software tool based on a microscopic simulation approach, which reproduces real traffic conditions. The program provides a detailed modelling of the traffic network, distinguishing between different types of vehicles and drivers and considering a wide range of network geometries. SITS uses a flexible structure that allows the integration of simulation facilities for any of the ITS related areas. This new simulation package is an object-oriented implementation written in C++. SITS allows also the analysis of signal control devices and different road geometries considering road junctions and access ramps.
The simulation model adopted in the SITS is a stochastic one. Some of the processes include random variables such as, individual vehicle speed and input flow. These values are generated randomly according to a pre-defined amplitude interval.
The overall model structure is represented on Figure 1.

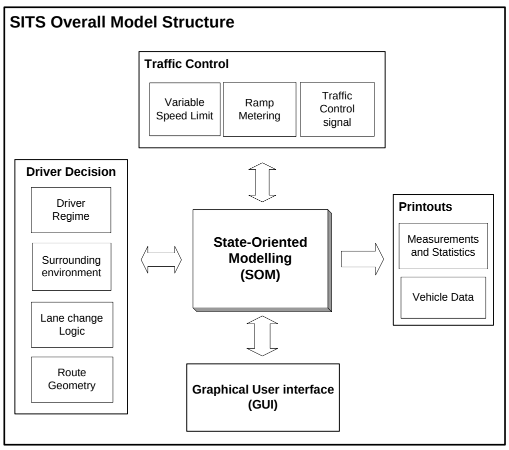

Figure 1: SITS overall Model Structure

In this structure, a nuclear module, State-Oriented Modelling, interacts with the Traffic Control and Driver Decision modules. The output of SITS consists not only in a continuously animated graphical representation of the traffic network but also the data gathered by the detectors, originating different types of printouts.

2.1 State-Oriented Modelling

SITS models each vehicle as a separate entity in the network according to the state diagram showing in figure 2 [2]. Therefore, are defined five states {1-aceleration, 2-braking, 3-cruise speed, 4-stopped, 5-collision} that represent the possible vehicle states in a traffic systems.

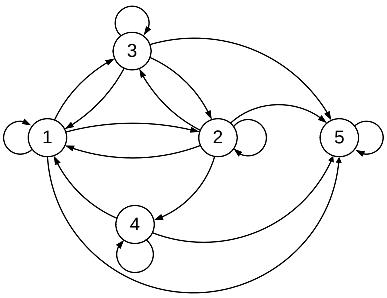

Figure 2: SITS state diagram: 1-aceleration, 2-braking, 3-cruise speed, 4-stopped, 5-collision

In this modelling structure, so called State-Oriented Modelling (*SOM*), every single vehicle in the network has one possible state for each sampling period. The transition between each state depends on the driver behaviour model and its surrounding environment. Some transitions are not possible; for instance, it is not possible to move from state #4 (stopped) to state #2 (braking), although it is possible to move from state #2 to state #4.
Included on the most important elements of SITS are the network components, travel demand, and driving decisions. Network components include the road network geometry, vehicles and the traffic control. To each driver is assigned a set of attributes that describe the drivers behavior, including desired speed, and his profile (*e.g.*, from conservative to aggressive). Likewise, vehicles have their own specifications, including size and acceleration capabilities. Travel demand is simulated using origin destination matrices given as an input to the model.

2.2 Driver Decision

At this stage of development the SITS implements different types of driver behaviour models, namely car following, free flow and lane changing logic. SITS considers each vehicle in the network to be in one of two driver regimes: free flow and car-following.
The free flow regime prevails when there is either (*i*) no lead vehicle in front of the subject vehicle or (*ii*) the leading vehicle is sufficiently far ahead that it does not influence the subject vehicles behaviour. In the free flow case the driver travels at his desired maximum speed.

Car-following regime dictates acceleration/deceleration decisions when a leading vehicle is near enough to the subject vehicle in order to maintain a safe following distance.

2.2.1 Perception-Driver Model

Accelerations and decelerations are simulated using the Perception-Driver Model (PDM). According with the PDM, the driver decides to decelerate/accelerate depending on two factors: the difference between the distance to the leading vehicle and the critical distance, and his active state. The critical distance $d_{c,n}$ is defined as follows:

$$d_{c,n} = d_{sb,n} + d_{f,n} + L_{n+1} \qquad (1)$$

where: $d_{sb,n}$ is the safety braking distance for the vehicle n, given by equation (2), $d_{f,n}$ is the following distance for the vehicle n, given by equation (5) and L_{n+1} is the length of the leading vehicle.
Figure 3 shows a schema of the critical distance for the n^{th} vehicle (assuming that the traffic conditions for both vehicles remain constant between time instants t_0 to t_1).
The safety braking distance $d_{sb,n}$ is given by:

$$d_{sb,n} = -\frac{\left(v_{n+1} - v_n\right)^2}{2\left(a'_n - s_{n+1}\right)} \qquad (2)$$

where: v_n is the current speed of vehicle n, v_{n+1} is the current speed of leading vehicle n+1, a'_n is the deceleration of vehicle n given by equation (3) and s_{n+1} is the deceleration/acceleration of the leading vehicle n+1, given by equation (3) or (4) depending on his current state.

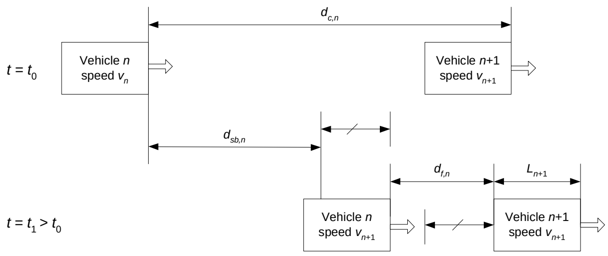

Figure 3: Critical distance schema

The driver reduces the speed by applying a deceleration a'_n. The model relates the vehicle performances with the driver characteristics.

$$a'_n = a'_{\max,c}\ \gamma_d \qquad (3)$$

where: $a'_{\max,c}$ is maximum deceleration for type c vehicle and γ_d is a parameter for type *d* driver ($0.1 < \gamma_d < 1.0$).
The value of γ_d can be changed at any time in order to prevent a collision. This parameter defines the driver

profile (*e.g.*, from conservative $\gamma_d = 0.1$ up to aggressive $\gamma_d = 1.0$).

The value of the deceleration/acceleration s_{n+1} depends on the state of the leading vehicle. If the vehicle is in state #2 then s_{n+1} is given by equation (3); otherwise if it is in state #1, s_{n+1} is given by equation (4). Therefore, $s_{n+1} = 0$ only when the vehicle is in one of the other states.

$$s_{n+1} = a_{\max,c}\ \gamma_d \qquad (4)$$

where: $a_{\max,c}$ is the maximum acceleration for a vehicle of type c.

The following distance $d_{f,n}$ depends on the speed of vehicle n and the associated driver profile, yielding:

$$d_{f,n} = v_n^2\ \gamma_d \qquad (5)$$

2.2.2 Lane Changing Model

The lane changing model in SITS uses a methodology that tries to mimic a driver behaviour when producing a lane change. This methodology was implemented in three steps: (*i*) decision to consider a lane change; (*ii*) selection of a desired lane; (*iii*) execution of the desired lane change if the gap distances are acceptable. A driver produces a lane change maneuver in order to increase speed, to overtake a slower vehicle or to avoid the lane connected to a ramp. After selecting a lane, the driver examines the lead g_b and lag g_a gaps in the target lane in order to determine if the desired change can be executed, as shown in Figure 4.

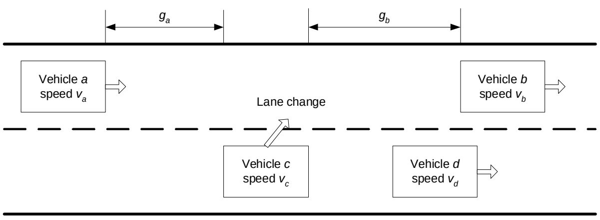

Figure 4: Lead g_b and lag g_a gaps for a lane change maneuver of vehicle n

If g_a and g_b are higher than the critical distances between vehicle a and c, and c and b, respectively, then the desired lane change is executed in a single simulation sampling interval Δt.

2.3 Graphical User Interface

The main types of input data to the simulator are the network description, the drivers and vehicles specifications and the traffic conditions. The output of SITS consists not only in a continuously animated graphical representation of the traffic network but also the data gathered by the detectors, originating different types of printouts.

SITS tracks the movements of individual vehicles to a resolution of $\Delta t = 10^{-2}$ sec and uses five different colours to represent the individual vehicle states; namely, stopped (red), acceleration (green), breaking (yellow), cruise speed (blue) and collision (black), as represented on figure 5.

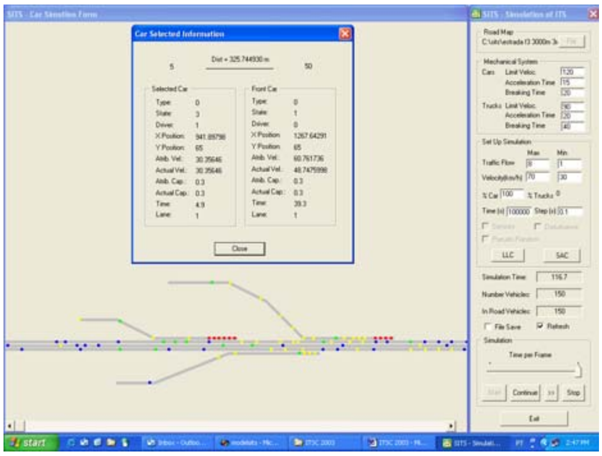

Figure 5: SITS animated graphical representation

3 MODEL CALIBRATION AND TESTING

The research group of Robert Bosh GmbH developed in 1998 a benchmark to analyze the quality of microscopic simulators by checking their ability to reproduce a macroscopic behaviour [3].this benchmark was also used to evaluate the performance of the AIMSUN simulator [4].

In [3] the authors test the macroscopic behaviour of a microscopic model by simulating the traffic on a cyclic one lane road with a length of l = 1000 m. A fixed number N of identical vehicles (4.5 m length) is set with a initial speed of v = 0 km/h, at randomly positions, having a limit free flow speed of $v = 54$ km/h. After elapsing the starting transient the steady-state traffic behaviour is recorded (the exact passing time and the speed value of each vehicle) at one measurement point during a period of 2 hours. The benchmark procedure consists on varying the number N of vehicles to accomplish different traffic densities Q and the corresponding traffic flow ϕ (Q).

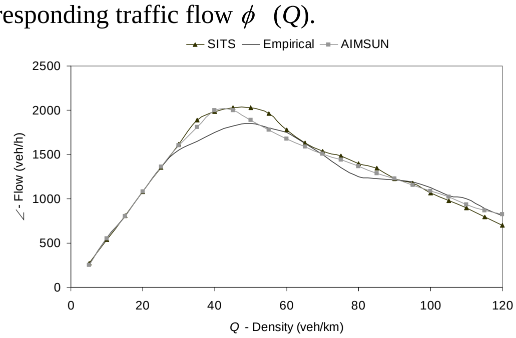

Figure 6: Empirical (macroscopic) versus SITS and AIMSUN simulated flow density curves

Having this benchmark in mind, Figure 6 plots the traffic flow ϕ *versus* its density Q for the empirical (macroscopic), the SITS and the AIMSUN [4] simulators. The output of SITS is clearly in accordance with the expected results. Moreover we have a maximum traffic flow of about 1800-2000 vehicles/km, which is known as a realistic value for long periods of measurement time.

4 CONCLUSIONS

In this paper, we described a software tool based on a microscopic simulation approach, to reproduce real traffic conditions in an urban or non-urban network. At this stage of development the SITS considers ramp metering and different types of driver behaviour model, namely car following, free flow, lane changing logic. In the next stage of development, we will include better driver behaviour models, such as, a driver time reaction model, and improve the graphical user interface through the development of a 3D simulation environment.

5 REFERENCES

[1] Figueiredo, L., I. Jesus, J. Machado, J. Ferreira and J. Santos. "Towards the Development of Intelligent Transportation Systems", in *Proc.4th IEEE Intelligent Transportation Systems Conference*, Oakland (CA), USA, 2001, pp. 1207-1212.

[2] Figueiredo, L., J. Machado and J. Ferreira. "On the Dynamics Analysis of Freeway Traffic", in *Proc.6th IEEE Intelligent Transportation Systems Conference*, Shanghai, China, 2003, pp. 358-363

[3] Manstetten D., W. Krautter and T. Schwab. "Traffic Simulation Supporting Urban Control System Development", in *Proc. 5th World Conference on Intelligent Transportation Systems*, Seoul, Korea, 1998.

[4] Barceló, J. and J.Casas. "Dynamic Network Simulation With Aimsun" in *Proc. Int. Symposium on Transport Simulation*, Yokohama, Japan, 2002.