DRACULA Traffic Microsimulation Model

Extracts from paper

DRACULA: a microscopic, day-to-day dynamic framework for modelling traffic networks*

by

Ronghui Liu, Dirck Van Vliet and David Watling

Institute for Transport Studies
University of Leeds
Leeds LS2 9JT
U.K.

* Paper submitted to Transportation Research A

5. THE TRAFFIC SIMULATION

The traffic model in DRACULA is a microsimulation of the movement of (pre-specified) vehicles through the network. Drivers follow their pre-determined routes and enroute encounter signals, queues and interact with other vehicles on the road. A large number of such microscopic vehicle models have been developed in the past at varying levels of complexity and network size (e.g. in some the network is effectively a single intersection) - a few are mentioned in Section 2. An essential property of all such models is that the vehicles move in real-time and their space-time trajectories are determined by, e.g., car following and lane-changing models and network controls such as signals. Rather than adopting an existing model, in DRACULA we elected to develop our own microsimulation model from scratch beacuse of the strong need to control the interaction between the supply and demand models and, in particular, the need to associate a specific route and destination with each vehicle.

The simulation is based on fixed time increments; the speeds and positions of individual vehicles are updated at an increment of one second. Spatially, the simulation is continuous in that a vehicle can be positioned at any point along a link. The model includes an animated graphical display of vehicle movements in the network.

The simulation starts by loading the simulation parameters, network data including global and local variations and trip information (demand and routes determined by the demand model). It then runs through an interative procedure at the pre-defined time increments, within which the following tasks are performed:

1. Update the state of traffic signal controls, and check if any incident starts or ends;
2. Generate new entry vehicles and place them on their entrance links;
3. Loop through all vehicles in the network, and for each one of them:
   (a) check if the vehicle wants to change lane and, if so, whether the gaps are acceptable;
   (b) update the vehicle's speed and acceleration and advance it to its new position. At the end of the link, either remove the vehicle from the network (if it arrives at its destination) or pass it to its next link en route;
   (c) calculate vehicle emissions and fuel consumption, and record traffic performance measures;
4. Update the graphical display if required;
5. Update the simulation clock and return to step 1.

Two additional time periods are simulated for each study (for example peak) period on each day: a warm-up period to ensure that the simulation does not start with an empty network and a cooling-off period which represents, say, the off-peak period. In the warm-up period trips are generated with flow rates increasing linearly from a pre-peak level (which is assumed to be half of the starting peak level) to the level at the start of the study period. During the study period trips generated by the demand model arrive on the network. In the cooling-off period flows arriving on the network are reduced gradually to an off-peak level, and the run continues until all trips generated by the demand model complete their journey.

The detailed traffic simulation is discussed next.

5.1. Network represention

The network is represented by nodes, links and lanes. A node is either external, where traffic enters or leaves the network, or an intersection. There is no restriction on the number of roads connected to an intersection.

A link is a directional roadway between two nodes and consists of one or more lanes. A link is specified by its upstream and downstream nodes, cruise speed, number of lanes, and turns permitted to other outbound links from the downstream node. For each permitted turn, the lane(s) in the link that can use this turn are specified and a marker describing its priority over opposing flows is given.

In the model traffic moves in lanes. A lane can be reserved for a particular type(s) of vehicles only (for example a reserved bus lane). The reservation is specified by its start and end position on the lane and, optionally, by a start and end time of its operation.Vehicles travel through an intersection along “inter-lanes” which are straight lines connecting the stopline of an inbound lane with the entrance of an outbound lane; the crossing point of two inter-lanes is a conflict point.

5.2. Vehicle generation

Vehicles are individually represented; each has a set of individual characteristics including vehicle type (car, bus, guided-bus, taxi, heavy goods vehicle); vehicle length; desired minimum distance headway; normal and maximum acceleration; normal and maximum deceleration; desired speed (relative to the mean speed on any individual link) and acceptable gap. These characteristics are randomly sampled from normal distributions representative of that type of vehicle:

$$p_t = \mathrm{Nor}(P_t, \beta_v^2 P_t^2) \tag{9}$$

where p_t is a random variable representing vehicle parameter p for vehicle type t and P_t is the average value for the type of vehicles. β_v is a user-defined coefficient of variation and is assumed to be independent to vehicle types. The characteristics for each vehicle are chosen at the start of a model run. The default values are based on a number of sources, including May (1990), Institute of Transportation Engineers (1982) and Gipps (1981).

Public transport vehicles are represented with additional information such as service number, service frequency, bus stops and average passenger flows at each bus stop, etc.

Vehicles enter the network at the upstream end of the entrance link (the first link en-route), with initial position and speed based on the position and speed of the preceding vehicle. If there is no space available in the entrance link, vehicles wait in a vertical queue at the upstream end of the link to enter the network at a later time.

5.3. Vehicle movement

Vehicle movements in a network are determined by its desired movement, response to traffic regulations and interactions with neighbouring vehicles. The simulation maintains a linked list of vehicles in each lane and moves individual vehicles according to a car-following model and a lane-changing model, and their response to traffic controls at intersections.

5.3.1. Car-following model

The car-following model calculates a vehicle’s acceleration in response to its desired speed and the relative speed and distance of the preceding vehicle. Depending on the magnitude of the relative distance, a vehicle is classified into one of three regimes: free-moving, following or close-following.

Free-moving: when a vehicle is the leading vehicle in its lane and its position relative to the stopline of the link is larger than a pre-defined threshold d^h, or if it is a following vehicle with a space headway larger than d^h, the vehicle accelerates or decelerates freely in order to maintain its desired speed.

Following: when the space headway becomes shorter than d^h but longer than a lower threshold d^l, the vehicle will take a controlled speed which is derived from the relative speed and distance of the preceding vehicle in a manner similar to that used in NEMIS (Mauro, 1991):

$$v_i^{following}(t) = c_1 v_i(t-\tau) + c_2 v_{i-1}(t) + c_3(x_{i-1}(t) - x_i(t-\tau) - L_{i-1} - s_i^{min}) \quad (10)$$

where *i* and *i-1* denote the subject and its preceding vehicle, *v* and *x* the speed and position of a vehicle, τ is the reaction time, L_i the length and s_i^{min} the minimum safety distance of the vehicle. Parameters c_1, c_2 and c_3 are constants.

Close-following: when the space headway is below d^l, the following vehicle will prepare to stop in case the preceding vehicle brakes suddenly. A Gipps' (Gipps, 1981) safety speed is used which has the following form:

$$v_i^{close}(t) = d_i\tau + \sqrt{d_i^2\tau^2 - d_i\{2[x_{i-1}(t-\tau) - x_i(t-\tau) - L_{i-1} - s_i^{min}] - v_i(t-\tau)\tau - v_{i-1}(t-\tau)^2/d'_{i-1}\}}$$

(11)

where d_i is the maximum deceleration of vehicle *i* and d'_{i-1} is the deceleration of vehicle *i-1* perceived by vehicle *i*; the latter is assumed to be the minimum of -3.0 and $(d_{i-1}$-3.0)/2 m/s^2. In the model, the vehicle's reaction time (τ) is assumed to be the same as the simulation step. The actual speed of the following vehicle *i* is:

$$v_i(t) = \min(v_i^{following}(t), v_i^{close}(t)) \quad (12)$$

In all cases, drivers will not want to move at a speed exceeding their desired one, accelerate at a rate exceeding their maximum acceleration, or decelerate above their maximum deceleration rate. When a vehicle moves at a speed below a minimum speed, the vehicle is regarded as stationary.

5.3.2. Lane-changing model

The lane-changing model contains three steps: (1) obtain the lane-changing desires and define the type of changing, (2) select the target lane, and (3) change lane if all gaps are acceptable.

The model divides drivers' lane-changing desires into one of five types when drivers have to or want to change lane in order to:

- (a) reach a bus stop on the link;
- (b) avoid a restricted-use lane or incident;
- (c) make their turn from the next junction;
- (d) move into a lane reserved for their type; or
- (e) gain speed by overtaking a slower moving vehicle.

The first three types are "mandatory", i.e. the lane-changing has to be carried out by a certain position on the current link; the other two types are "discretionary". Whether a discretionary lane-change can be carried out depends on the actual traffic conditions. For example, a vehicle would only change lane to gain speed if the speed offered by the adjacent lane is higher by a pre-defined factor.

When a vehicle wishes to change lane, it looks for a target lane. The target lane is generally determined by the lane-changing requirement, except in the case of overtaking which is only permitted from the nearside to the offside. Once it has chosen a target lane, it examines the "lead" and "lag" gaps in its target lane, and makes the lane-changing movement immediately if both lead and lag gaps are acceptable. For discretionary lane-changing, a gap g_i for vehicle i is acceptable if it is greater than a minimum safety distance G_i^{min} which the vehicle wants to keep in case the preceding vehicle breaks suddenly:

$$G_i^{min} = v_i * \tau + v_i^2/(2*d_i) - v_{i-1}^2/(2*d_{i-1}) + s_i^{min}$$
(13)

The acceptable gap for mandatory lane-changing decreases as the vehicle gets closer to its 'target point'. The target point can be a bus-stop, the position of an incident, or the end of the queue from the stopline (in the case of lane-changing for next junction turning). If a vehicle gets nearer to its target point but has not been able to change to the target lane, the vehicle may slow down and eventually stop and wait for an opportunity to change lanes. When the speed on the target lane is below a pre-defined threshold, some drivers on the target lane may deliberately slow down in order to create gaps for the subject vehicle to join. These drivers are randomly selected from a pre-defined proportion which is related to the type of subject vehicle (for example, there might be a higher proportion of people willing to giveway to buses than to cars).

Vehicles can only change one lane at a time. After one such manoeuvre, the vehicle has to wait for a pre-defined period of time before making another lane-changing attempt.

5.3.3. Intersection simulation

Vehicles start to react to traffic controls (signals or giveway) at a downstream intersection when they are within the distance d^h from the stopline. Only the lead vehicle in each lane reacts to intersection control; the following vehicles follow the preceding ones according to car-following rules until they become the lead vehicle. Three types of intersections are modelled: signalised, giveway and roundabout.

At a signalised intersection, when the signal has just changed to green, the head of the queue checks whether its path is clear before moving off. During the remaining green period, vehicles move across the intersection at a speed determined by the car-following rules: the lead vehicle follows the last vehicle in the outbound lane it turns into. At the instant the signal changes to amber, the vehicle nearest to the stopline will consider whether to stop. If it is too close to the stopline, it will either go ahead if it can pass the stopline within the amber period with its current speed, or alternatively make a random decision whether to carry on moving or to stop. If the decision is to stop, it applies its maximum deceleration if necessary; similarly, if it decides to go on, it may accelerate at its maximum acceleration rate. This decision is then maintained throughout the remaining amber period. A vehicle is allowed to move across at the start of a red signal only if it can not stop at the stopline with its maximum deceleration.

Travelling towards a giveway intersection, vehicles will aim to stop just before the stopline, and only when they are a few metres away from the stopline where they can see the situation on the major road will they start to look for gaps to join in or to cross the major flows. The acceptable gap is individual based and can vary with the length of time the individual has waited at the giveway sign. Vehicles approach a roundabout as though approaching a priority junction and give way to circulating traffic on the roundabout.

5.4. Simulation outputs

The traffic simulation records the link travel times for each demand trip and passes this information to the driver learning process where the individuals update their perception of the network incorporating today's travel experience.

As a measure of network performance, the simulation also outputs (by default) network, link and route specific measures such as average travel time, speed, queue length, fuel consumption and pollutant emission over regular time periods defined by the user. At the user's request, the program may also output vehicle trajectories. A graphical animation of the vehicles' movements can also be shown in parallel with the simulation, giving the user a direct view of the traffic condition on the network.