Simulation of vehicle platooning via differential equations

The work of [Wan14] has been taken as a reference to implement a simple approach to simulation of vehicle plattoning. The only use of differential equations limits the applicability of realistic communication infrastructures (such as the emulation of a real 802.11p device), but it simplifies the structure of the simulator and helps evaluate several other operating conditions.

Being $\boldsymbol{v}$ and $\boldsymbol{d}$ the vectors of speed and reciprocal distance of the vehicles, the following system dynamics is considered:

$$\dot{v}_i = {}^{1}/_{m_i}\left(F_i - \left(a_i + b_i \cdot v_i^2\right)\right);\ \dot{d}_i = v_{i-1} - v_i; i = 0, \dots N-1$$

with control law:

$$F_i = g(d_i), i \geq 1;\ g(d) = \max\{50(d-27) + 4(d-27)^3, -10000\}$$

N+1 being the number of cars in the platoon (index $i = 0$ denotes the leader of the platoon), a_i the tire/road rolling resistance, b_i the aerodynamic drag, m_i =1050 Kg, $i = 0, \dots N-1$ the weight of the cars. The braking force applied by the leader is F_0. Variable communication delays (*del*) between the vehicles are considered as well.

Structure

A discrete time event simulator has been implemented by applying a continuos-to-discrete conversion of the differential equations. The events of interest are related to the receipt of messages exchanged by vehicles about their accelleration, speed and position. Any Quality of Service metric may be easily applied to the communication messages, such as loss of delay of the packets. The inherent time evolution of the platoon is then available, once a sudden brake, or any other unexpected behaviour, takes place. The simulation loop is inserted into a main loop, in which the system parameters are set randomly, thus driving the registration of events under different operating conditions, such as initial speed and distance of vehicles in the platoon. The final result is a database of system parameters and corresponding performance, such as collision or not in the platoon. In turn, the database is analyzed by machine learning in order to synthetize a model for performance prediction.

Example

The first presentation of the simulator was at the SafeCOP[1] technical WP workshops at DTU Compute, Nov. 2016, in which it was shown how the simulator may drive data to feed data analytics for collision prediction (presentation attached in the git repository).

References

[Wan14] L. Xu, L. Y. Wang, G. Yin and H. Zhang, "Communication Information Structures and Contents for Enhanced Safety of Highway Vehicle Platoons," in IEEE Transactions on Vehicular Technology, vol. 63, no. 9, pp. 4206-4220, Nov. 2014.

[1] www.safecop.eu.