Dealing with the right of way in advanced traffic simulation. A characterization of drivers' behaviours in a multi-agent approach.

Reffet B[1,2], Mathieu P[2], Kemeny A[1,3], Vailleau B[1], Nongaillard A[2] and Mohellebi H[1]

(1) Renault, France, e-mail : {berenice.reffet, andras.kemeny, benjamin.vailleau, hakim.mohellebi}@renault.com
(2) Universite de Lille 1, France, e-mail : {philippe.mathieu, antoine.nongaillard}@univ-lille1.fr
(3) Arts et Metiers ParisTech, France

Abstract - *With the emergence of ADAS and autonomous vehicle, the need of simulation software to test advanced systems and models is unavoidable. The objective of this work is to characterize, in a multi-agent approach, the traffic vehicles behaviours, and to model them in a versatile traffic simulator, serving as a testing tool for integration in the traffic module of the SCANeR Studio*^{TM} *simulation software. The algorithm will bring more natural interactions between vehicles in simulation and allow the emergence of new relevant situations for autonomous vehicles, observable in real, such as collision risk situations or even accidents, which have for now to be scripted in scenarios and do not occur naturally.*

Keywords: *Drivers' behaviour, multi-agent systems, traffic, artificial intelligence, simulation.*

Introduction

With an increasing number of ADAS systems and incoming Autonomous Vehicles (AV), a huge amount of physical driving tests is needed (hundreds of millions of km) [Koo16] to validate systems. The use of numerical simulation is then crucial to reduce this amount of real tests, by covering a range of situations as large as required [Mas12].
Most of current simulation softwares : PTV Vissim[1], ARCHISIM [Esp07], AIMSUN[2], TrafficGen [Bon14] etc., do not yet include sufficiently fine microscopic traffic modules for AV testing in terms of driver behaviour modelling and cooperative driving [Baz14, Mic85]. It is then difficult to confront simulated AV to real like situations, especially critical situations in which behaviour of the automated systems is expected to achieve customer performance with the necessary safety requirements [Baz13].
Drivers' behaviours are various and changing, and they are at the origin of a great variability in road traffic situations. This disparity is generally related both to the human perception system (inter-individual differences), and to decision making mechanisms, as well as the actions and manoeuvres resulting from them [Wri02]. In our approach, we introduced this variability in perception and decision to our traffic agents' models, in order to have more natural and realistic behaviours.

Methodology

Model of driving mechanisms can be schematized as in Figure 4.

The driver receives information from the environment

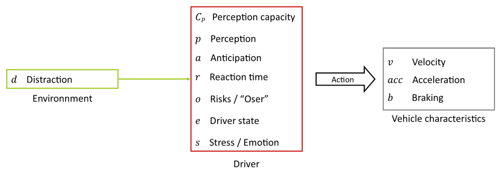

Figure 1: Scheme of main driving mechanisms.

and uses it to decide the action to do on the vehicle by acting on speed, acceleration/deceleration and steering wheel.

This mechanism is implemented in a multi-agent simulation tool, Netlogo, where the agents represent vehicles and infrastructure elements.

Tree main behaviours can be found in the literature. [Wri02] :

The first one, is what usually can be considered as cautious behaviour. It can be described by a strict respect of the traffic code and a tendency to drive slowly as the other drivers and with an increased safety distance.

The second one, corresponding to a more aggressive behaviour, can be described by a no respect of the traffic code and a tendency to drive faster as the other drivers and with a decreased safety distance.

The third one, would be a standard behaviour, described by a complete respect of the traffic code, neither more, neither less.

In our work, we propose to add one more we call the normal driver. It may vary in function of his or her

Parameters	Cautious	Agressive	Normal	Standard
D_S *in m*	$\in [0;100]$	$\in [0;30]$	$\in [0;100]$	$\in [0;100]$
$\vec{V_E}$ *in km/h*	$\in [0;130]$	$\in [0;250]$	$\in [0;250]$	$\in [0;130]$
$(\vec{v_{f_i}}, \vec{v_{b_i}}, \vec{v_{r_i}}, \vec{v_{l_i}})$ *in km/h*	$\in [0;250]$[4]	$\in [0;250]$[4]	$\in [0;250]$[4]	$\in [0;250]$[4]
$(d_{f_i}, d_{b_i}, d_{r_i}, d_{l_i})$ *in m*	$\in [0;1500]$	$\in [0;1500]$	$\in [0;1500]$	$\in [0;1500]$
$((\alpha_f;d_f),(\alpha_b;d_b),(\alpha_r;d_r),(\alpha_l;d_l))$ *in° and in m*	$\alpha_j \in [0°, 180°]$ *and* $d_j \in [15;1500]$	$\alpha_j \in [0°, 180°]$ *and* $d_j \in [15;1500]$	$\alpha_j \in [0°, 180°]$ *and* $d_j \in [15;1500]$	$\alpha_j \in [0°, 180°]$ *and* $d_j \in [15;1500]$
r_O *in %*	$\in [0;75]$	$\in [0;100]$	$\in [0;100]$	$\in [0;75]$
r_S *in %*	$\in [0;75]$	$\in [0;100]$	$\in [0;100]$	0
s_L *in km/h*	$\in S_L$	$\in S_L$	$\in S_L$	$\in S_L$
T_R *in %*	$\in [0;100]$	$\in [0;75]$	$\in [0;100]$	100
t_l *in s*	$1s$	$1s$	$1s$	$1s$

Figure 2: The driver parameters.

Overtaking	Moving back in the lane	Acceleration	Braking
No vehicle laterally	No vehicle laterally	Vehicle laterally	Vehicle laterally
Overtaking autorized	Overtaking autorized	Overtaking forbidden	Overtaking forbidden
No indicator	No indicator	Indicator	Indicator
$T_{F_i} < t_F$	$T_{F_i} < t_F$	$T_{F_i} > t_F$	$T_{F_i} < t_F$
$T_{LF_i} \geq t_{F_1}$	$T_{LF_i} \geq t_{F_1}$	$T_{LFi} \leq t_{F_1}$	$T_{LF_i} \leq t_{F_1}$
$T_{B_i} < t_B$	$T_{B_i} < t_B$	$T_{B_i} < t_B$	$T_{B_i} > t_B$
$T_{LB_i} > t_{LB}$	$T_{LB_i} > t_{LB}$	$T_{LB_i} < t_{LB}$	$T_{LB_i} < t_{LB}$
$Y_{F_i} < y_F$	$Y_{F_i} < y_F$	$Y_{F_i} > y_F$	$Y_{F_i} > y_F$
$Y_{LF_i} > y_{LF}$	$Y_{LF_i} > y_{LF}$	$Y_{LF_i} < y_{LF}$	$Y_{LF_i} < y_{LF}$
$Y_{B_i} < y_B$	$Y_{B_i} < y_B$	$Y_{B_i} > y_B$	$Y_{B_i} > y_B$
$Y_{LB_i} > y_{LB}$	$Y_{LB_i} > y_{LB}$	$Y_{LB_i} < y_{LB}$	$Y_{LB_i} < y_{LB}$

Figure 3: The overtaking's decision rules.

organisation, or driving spirit. It can be considered of a mixed of the three lasts described.

Our model is based on three main components : perception, anticipation, and decision rules. - Each agent of the traffic has a perception perimeter, with speed, position and time to collision (TTC) with other vehicles inside this perimeter, as well as position and state off static agents such as traffic light or traffic signs for example. - Anticipation is characterized by an estimation of perception state at a given temporal horizon. - Decision rules are condition that have to be satisfied in order to trigger a manoeuvre.

Variability across traffic agents is provided by a variability on perception parameters. Moreover, an error is pseudo-randomly (distribution on traffic population) introduced in perception and anticipation to provide more realistic non-perfect behaviours.

To validate our approach on a manoeuvre, we first chose to prototype the methodology in the case of overtake on a 2 lanes highway.

In this case, perception parameters are following :

With :

— D_S the safety distance
— $\vec{V_E}$ the speed of the ego car
— $(\vec{v_{f_i}}, \vec{v_{b_i}}, \vec{v_{l_i}})$ the speed of other vehicles (f for front, b for back, l for the lateral lane)
— $(t_{f_i}, t_{b_i}, t_{l_i})$ the time to vehicle i (in front, back, on the lateral lane)
— $((\alpha_f; d_f), (\alpha_b; d_b), (\alpha_r; d_r), (\alpha_l; d_l))$ the field of view of the ego car
— r_O the overtake risks
— r_S the speed risk
— $S_L = /20; 30; 40; 50; 70; 90; 110; 130/$ the speed limit
— T_R the respect of traffic code
— t_l the reaction time/latency

These parameters are then correlated to the following overtaking decision rules :

For the implementation we choose the Netlogo language, and our algorithm takes into account the overtaking on a road with two lanes. A crossing in T is under development.

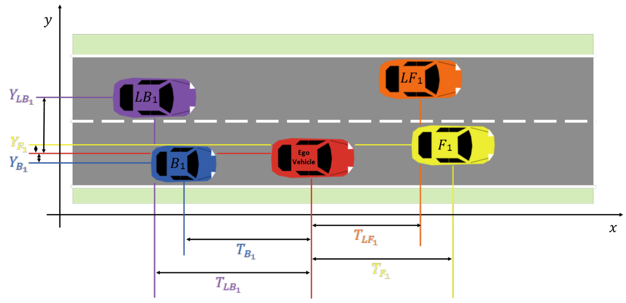

Figure 4: Diagram of the perception of our vehicles.

Expected results and discussions

The Multi-agent systems allows to model interactions between agents designed for large scale simulation. This methodology is more focused on the interactions than the agents and incremental design of simulations is thus supported intuitively and easily. Validation of the proposed algorithm will be done through the measurement of the rate of accidents or critical situations occurring during a simulation thanks to errors on perception and anticipation for some agents. The objective of the studied algorithm is to improve the overall traffic with realistic driving behaviour. We expect to show some accidents for agents with error and smoother manoeuvres for agents with good level of anticipation. This methodology will then be applied to cross intersection driving and to other cases and manoeuvres.

Conclusion

As our work show the better realism of behaviours thanks to the proposed models, it illustrates the new and more efficient way of testing which will be needed with a very large number of representative traffic scenarios for ADAS and automated vehicle functions. Indeed, to validate the corresponding embedded systems, automobile companies and road research institutes need today a realistic traffic which can reproduce the accidents that may arise in function of different and realistic driving behaviours. New implementation of the resulting enhanced traffic model will help automotive OEMs and suppliers to test the autonomous vehicle strategies in a simulated realistic traffic and allow both driver in the loop and high-performance computer (HPC) simulation validation in numerous critical situations for self-driving cars.

References

A. L. Bazzan and F. Klügl, **Introduction to Intelligent Systems in Traffic and Transportation**, *Synthesis Lectures on Artificial Intelligence and Machine Learning*, vol. 7(3) : 1–137, 2013.

A. L. C. Bazzan and F. Klügl, **A review on agent-based technology for traffic and transportation**, *The Knowledge Engineering Review*, vol. 29(03) : 375–403, 2014.

A. Bonhomme, P. Mathieu and S. Picault, **A Versatile Description Framework for Modeling Behaviors in Traffic Simulations**, in 2014 IEEE 26th International Conference on Tools with Artificial Intelligence, 937–944, 2014.

A. Bonhomme, P. Mathieu and S. Picault, **A Versatile Multi-Agent**

Traffic Simulator Framework Based on Real Data, *International Journal on Artificial Intelligence Tools*, vol. 25(01) : 1660006, 2016.

S. Espié and J.-M. Auberlet, **ARCHISIM : a behavioral multi-actors traffic simulation model for the study of a traffic system including ITS aspects**, *International Journal of ITS Research*, vol. Vol5(n1) : p7–16, 2007.

P. Koopman and M. Wagner, **Challenges in Autonomous Vehicle Testing and Validation**, *SAE International Journal of Transportation Safety*, vol. 4(1) : 15–24, 2016.

A. Mas, **Utilisation des simulateurs de conduite pour l'évaluation des systèmes d'aide à la conduite en situation d'urgence**, Ph.D. thesis, Arts et Métiers ParisTech, 2012.

J. A. Michon, **A Critical View of Driver Behavior Models : What Do We Know, What Should We Do ?**, in L. Evans and R. C. Schwing, eds., Human Behavior and Traffic Safety, 485–524, Springer US, 1985, ISBN 978-1-4612-9280-7 978-1-4613-2173-6, dOI : 10.1007/978-1-4613-2173-6_19.

Ministère de l'Intérieur, Dépliant-Sécurité-Routière-2010, 2011.

A. Smiley, Conception de Panneaux de Signalisation qui Répondent aux besoins et Préférences du Consommateur, 2010.

S. Wright, N. J. Ward and A. G. Cohn, **Enhanced Presence in Driving Simulators Using Autonomous Traffic with Virtual Personalities**, *Presence : Teleoperators and Virtual Environments*, vol. 11(6) : 578–590, 2002.

[1] http ://vision-traffic.ptvgroup.com/fr/produits/ptv-vissim/
[2] http ://www.aimsun.com/