école doctorale **sciences pour l'ingénieur et microtechniques**

PhD title :

Socially smart connected and autonomous vehicle: Deep reinforcement learning for safe and efficient cooperative intersection.

Host laboratory :

Connaissance et Intelligence Artificielle Distribuées (CIAD)

Speciality of PhD:

Computer Science

Keywords :

Connected and autonomous vehicle, deep reinforcement learning, Socially intelligent robots

Job description :

Intersection management is at the core of studies for improving traffic conditions. In the half of last century, traffic lights have significantly contributed to the growth of traffic in terms of throughput and velocity through time assignment of the intersection space to conflicting flows. Initially, designed to improve the safety, they have benefited from several theoretical and technological advances to increase the traffic performance. However, traffic lights do not fully use the potential of CAV. More precisely, CAVs introduce the following novelties:

- Sequence formation: CAVs can wirelessly negotiate together to determine which CAV crosses the intersection first, which one the second and so on [1],
- Trajectory planning: Each CAV can autonomously adjust its speed according to the current and future obstacles coming from the other roads [2].

The thesis work focuses on cooperative intersection management of CAVs. This subject is in the topicality of this decade. On the one hand, the cooperative intersection management has a great potential to increase the road network capacity and to save energy in the future urban transportation. On the other hand, it can currently used in industrial sites to enhance the productivity of automated guided vehicles (AGV). Nevertheless, from the theoretical point of view, CIM raises the following challenge: Both sequence and (speed profile) trajectory need to be optimized together with respect to real-time constraints [3]. The former problem raises a combinatorial optimization problem whereas the second is a control of continuous system with time delay. To overcome the challenge, the thesis explores the potential of multiagent deep reinforcement learning.

Recently, deep reinforcement learning [4-5] is one of the most widely used methods to successfully control autonomous vehicles. It allows accomplishing complex driving tasks, by learning from real situations as well as from simulated situations with fuzzing techniques to consider extreme cases. Nevertheless, this technique is currently used only to control a single vehicle. Many situations in the field of transportation require interactions between connected and autonomous vehicles (CAV) to leverage the traffic congestion. These interactions can be either conflicting as in the case of intersection or collaborative as when CAVs should find a consensus to invite the pedestrian to cross the road [6]. In both cases, the CAV's movements must be synchronized to accomplish their tasks safely. Multi-agent deep reinforcement should help but is still an open research subject that needs to be thoroughly addressed [7]. This thesis will focus on conflicting situations.

A first stage of the thesis work is to compare the ability of different DRL agents to adapt themselves to the intersection of two CAVs. This stage allows to select the agent that will be used to extend the approach to a more complex intersection with many CAVs. To this end, two approaches are explored. The first one consists in defining a dynamic vehicle driving policies (aggressive, courteous, selfish or groupish …) [8] that is dynamically adapted according to the traffic context. The second one is to use metaheuristics to compute the sequences and train the DRL agents to respect the dynamic sequences. The result of the thesis can be extended to the cooperation between CAV and human-driven vehicles at intersections [9].

The PhD student will benefit from the experience of a pioneer team in the subject. The team exhibited the first real cooperative intersection management of three CAVs in ITS World Congress in 2015. It also wins the second place among 374 participants in the DAI2020 SMARTS Competition of Autonomous Driving organized by Huawei. She/he benefits from a well-equipped laboratory with platforms that include a microscopic traffic simulator, a high computation capability, small robots and three real vehicles open to be controlled.

Figure 1. Real demonstration of cooperative intersection management with autonomous vehicles (ITS WC 2015, Bordeaux, France)

References :

[1] J.Wu, F. Perronnet, and A. Abbas-Turki, “Cooperative vehicle-actuator system: A sequence-based framework of cooperative intersections management,” IET Intelligent Transport Systems, vol. 8, no. 4,pp. 352–360, 2013.

[2] A. Malikopoulos, C. G. Cassandras, and Y. J. Zhang, “A decentralized energy-optimal control framework for connected automatedvehicles at signal-free intersections,”Automatica, vol. 93, pp. 244–256, 2018.

[3] Zhong, Z., Nejad, M., & Lee, E. E. (2020). Autonomous and Semiautonomous Intersection Management: A Survey. IEEE Intelligent Transportation Systems Magazine, 13(2), 53-70.

[4] Ning, Z., Zhang, K., Wang, X., Obaidat, M. S., Guo, L., Hu, X., ... & Kwok, R. Y. (2020). Joint computing and caching in 5G-envisioned Internet of vehicles: A deep reinforcement learning-based traffic control system. *IEEE Transactions on Intelligent Transportation Systems*.

[5] Shin, M., Choi, D. H., & Kim, J. (2019). Cooperative management for PV/ESS-enabled electric vehicle charging stations: A multiagent deep reinforcement learning approach. *IEEE Transactions on Industrial Informatics*, *16*(5), 3493-3503.

[6] Zhang, M., Abbas-Turki, A., Lombard, A., Koukam, A., & Jo, K. H. (2020, September). Autonomous vehicle with communicative driving for pedestrian crossing: Trajectory optimization. In *2020 IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC)* (pp. 1-6). IEEE.

[7] Gupta, J. K., Egorov, M., & Kochenderfer, M. (2017, May). Cooperative multi-agent control using deep reinforcement learning. In *International Conference on Autonomous Agents and Multiagent Systems* (pp. 66-83). Springer, Cham.

[8] Lombard, A., Abbas-Turki, A., & El-Moudni, A. (2018). V2V-Based Memetic Optimization for Improving Traffic Efficiency on Multi-Lane Roads. *IEEE Intelligent Transportation Systems Magazine*, *12*(1), 35-46.

[9] Sadigh, D., Landolfi, N., Sastry, S. S., Seshia, S. A., & Dragan, A. D. 2018. Planning for cars that coordinate with people: leveraging effects on human actions for planning and active information gathering over human internal state. *Autonomous Robots*, *42*(7), 1405-1426.

Candidate Profile :

Master's degree in computer science, skilled in oriented object programming languages (mainly Python and C#)

Experiences in DRL and/or in 3D simulation are appreciated

Supervisors:

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