PhD Proposal

Multi-level cooperation between driver and automated vehicle for the management of complex situations: Application to the roundabout use case.

Location: LAMIH UMR CNRS 8201, Automatic Control Department – Hauts-de-France Polytechnic University, Valenciennes.

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Regional positioning:

- "Automated vehicles" topic and AV-Lab platform of CPER RITMEA program 2021-2027
- Strategic objective "Autonomous vehicles" of the FR CNRS 3733 TTM

Funding: 50% UPHF, 50% Région HdF

Scientific context

Automated vehicles currently traveling on road networks only operate in simple environments (one-way lanes) and generally at low speeds when the system makes decisions autonomously (lane changes). The larger-scale deployment of automated vehicles requires increasing the capabilities of the systems to manage more complex situations (intersections with different priority rules and roundabouts in particular) requiring at the same time to make decisions in constrained time on the basis predicted trajectories of other vehicles present in the environment.
The unsignalized roundabout is renowned for being among the most complex nodes because its crossing firstly requires control in a trajectory of most of the maneuvers that an automated vehicle must perform when navigating in an urban environment (e.g., insertion, keeping on the lane, changing lanes), while having a curved movement (not rectilinear) during the succession of maneuvers. The second challenge of the roundabout concerns its dynamic aspect: it can be dense and heterogeneous (e.g., presence of vehicles and/or cyclists), requiring the automated vehicle to anticipate the intentions of its users and react to unforeseen situations by adapting its path.
To move forward in solving these complex problems, the LAMIH Automatic control department has developed an approach based on haptic shared control and multi-level driver-vehicle cooperation which has demonstrated its ability to manage highly constrained situations in a simpler context: the highway (insertion, lane change, overtaking, exit) [1]. This same approach was used as part of the development of a system based on progressive learning methods to change the behavior of the automaton in this same situation [2].

Objectives

The objective of this research is to extend this approach to the complex environment which is the roundabout and thus to:

1. Define a trajectory to follow allowing the automated vehicle to cross an intersection while respecting the driving rules and the structure of the infrastructure to be crossed. This trajectory will be built on the basis of primitives usable in different contexts (insertion, lane following, lane change, exit, etc.). This trajectory must also be achievable and meet the vehicle's constraints (e.g., maximum acceleration/deceleration, maximum steering angle, etc.).
2. Assess the risk of surrounding dynamic elements using appropriate risk assessment metrics so that the automated vehicle can navigate safely. An important aspect of these metrics is that they must consider anticipation of the surrounding vehicles trajectories.
3. Make decisions in accordance with the risks and the driver's intentions (possible haptic shared control intervention) to trigger the transition between the successive primitives which constitute the overall crossing trajectory.
4. Guarantee the safety of the overall system throughout the duration of the crossing

From a methodological point of view, the thesis will aim to extend the multi-level driver-vehicle cooperation architecture previously developed in the lab [3], [4] to take into consideration the specific case of the roundabout. Contributions will concern path planning (polynomial methods or potential fields), prediction of vehicle trajectories from the environment (dynamic models of vehicles and possibly drivers, reconstruction of non-measurable variables: observers, etc.), estimation risk (classic metrics such as TIV, TTC, MRAM-CS, or to be defined), decision-making (multi-criteria methods or based on statistical tests) and finally robust control.

From an application point of view, the objective of the work consists of prototyping, testing and validating the developed approaches on a car driving simulator (LAMIH SHERPA simulator) and using a real vehicle prototype (PRIVAC/DS7) on the Gyrovia test track .

Gyrovia test track at the Transalley Valenciennes technopole, PRIVAC/DS7 vehicle prototype and the LAMIH SHERPA simulator.

<u>Main missions</u>

The PhD work is organized around four main steps.

- The first step consists in defining the complex driving situations that will be addressed in the PhD, e.g., insertion, roundabout, crossroads, etc.
- The second step aims at developing progressive learning algorithms based on the execution of maneuvers in shared or manual driving to achieve a refined driver model in the selected driving situations. On this basis, new robust shared control algorithms to solve the driver-automation conflict issue will be developed.
- The third step is to develop new robust trajectory planning and control algorithms for conflict resolution and the development of adaptive strategies for automated vehicle driving. The transition from one strategy to another will depend on elements from the environment but also on behavioral indicators from the previous phase. Driving strategies and maneuvers will be implemented in the form of robust local trajectory planning and control algorithms.

- The fourth step is to integrate the proposed shared control architecture into the dynamic driving simulator SHERPA-LAMIH for performance evaluation. It also aims to set up a functional validation experiment in real conditions using testing means (PRIVAC/DS7 vehicle prototype).

Candidate profile

Applicants must hold, or be near completion of a Master's degree or equivalent in systems and controls, applied mathematics or a related subject, with strong theoretical background and interest in Control Engineering and Vehicle Engineering. The candidate must show a strong interest to engage in innovative high-profile research. Fluency in English is required. Knowing French is a plus. Interested applicants do feel free to contact us for further details.

Keywords

Trajectory prediction and path planning, Human-machine cooperation, progressive learning, multi-objective optimization, haptic shared control, robust control.

To apply send a complete application to Chouki.Sentouh@uphf.fr and Jean-Christophe.Popieul@uphf.fr

The application must include:

1. CV including your relevant professional experience and knowledge.
2. A brief statement of motivation and research interests with names and email addresses of at least two referees, explaining why do you want to pursue a PhD, what are your academic interests, how they relate to your previous studies and future goals.
3. Copy of degree certificate(s) and academic transcripts of records from your previously attended university-level institutions.

After a first selection step, you will be invited to submit your application file on the ADUM website.

Do not hesitate to contact us for further information.

References

[1] Mohamed Amir Benloucif. Coopération Homme-Machine Multi-Niveau entre le Conducteur et un système d'automatisation de la conduite. PhD thesis, Université de Valenciennes et du Hainaut-Cambrésis, avril 2018.

[2] Mohamed Oudainia. Contrôle partagé adaptatif et élaboration de stratégies de conduite personnalisées pour le véhicule automatisé: une approche par apprentissage progressif. PhD thesis, Université Polytechnique Hauts de France, décembre 2023.

[3] Sentouh C., Nguyen A.-T., Benloucif M., Popieul J.-C. (2019). Driver-Automation Cooperation Oriented Approach for Shared Control of Lane Keeping Assist Systems. IEEE Transactions on Control Systems Technology, 27 (5), pp. 1962-1978.

[4] Benloucif M., Nguyen A.-T., Sentouh C., Popieul J.-C. (2019). Cooperative Trajectory Planning for Haptic Shared Control between Driver and Automation in Highway Driving. IEEE Transactions on Industrial Electronics, 66 (2), pp. 9846-9857, ISSN 0278-0046.

[5] M. R. Oudainia, C. Sentouh, A. -T. Nguyen and J. -C. Popieul, "Adaptive Cost Function-Based Shared Driving Control for Cooperative Lane-Keeping Systems With User-Test Experiments," in *IEEE Transactions on Intelligent Vehicles*, vol. 9, no. 1, pp. 304-314, Jan. 2024, doi: 10.1109/TIV.2023.3317979.