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

Titre de la thèse/Thesis title: Perceptual Confidence in cooperative Vehicular Environments

Laboratoire d'accueil / Host Laboratory: FEMTO-ST/DISC

Spécialité du doctorat préparé/Speciality : Informatique/Computer Science

Mots-clefs / Keywords: connected autonomous vehicles, C-V2X, road users safety, environment perception

Descriptif détaillé de la thèse / Job description

1. Research context:

Cooperative or collaborative perception is widely viewed as the panacea to truly realise autonomous driving [1], particularly in dense urban environments. Autonomous driving makes it possible for connected and autonomous vehicles (CAVs) to interact with one another, with the infrastructure of the road, or with other vulnerable road users, such as pedestrians and cyclists carrying mobile devices. The objective is to enhance traffic efficiency and road safety [2]. Maintaining real-time situational awareness of the environment for autonomous vehicles is difficult to achieve solely through the vehicle's perceptual capabilities, due to the limited environmental perception information, computing, and communication resources. The Society of Automotive Engineers (SAE) [3] categorises autonomous vehicles into six levels of autonomy. Most currently available commercial features fall under level 2 and level 3, referred to as advanced driving assistance systems (ADAS). Therefore, to overcome the limitations of perception and computation in autonomous driving above level 3, a collaborative perception (CP) system needs to be developed by incorporating advanced sensing technology, edge computing, 5G communication, and other technologies.

Recent ongoing research aims to address CP by enhancing sensor fusion techniques, decision making capabilities, and the use of edge/direct cooperation to enhance perception accuracy. While these remain active and open research areas, the challenge of deriving strong confidence/belief in a vehicle's perceived environment based on evidence (local & shared sensor readings) is under-addressed in the literature. In a vehicular environment, such sensor readings may be subject to spatial correlations, occlusions, limited perception range, or sensor specific detection inaccuracies e.g. under certain weather conditions. Given imperfect information, it is crucial to understand the complex relationship between stakeholders in a cooperative perception environment and how the theory of belief functions can be applied in an empirical environment to improve overall vehicular confidence in perception and by extension improve the safety. Thus, the challenge of fusing such inconsistent, incomplete, and potentially conflicting evidence (e.g. one reading identifying a pedestrian vs another a slow-moving motorbike) to determine belief/confidence in the environmental perception is a nontrivial challenge.

The project will investigate how the theory of belief functions can be used to reason under uncertainty by fusing diverse sensor readings and environmental awareness to enhance confidence in perception of urban vehicular environments.

2. Research objectives:

The project will leverage theory of belief functions to determine perceptual confidence applied to the domain of cooperation perception in a vehicular context. In other words, if a vehicle or edge device receives numerous cooperatively shared sensor readings from neighbouring vehicles or infrastructure, and these readings exhibit diverse and perhaps lower confidence levels, the proposed model will fuse these with spatio-temporal and environmental information to derive a higher certainty i.e. confidence in knowing.

The key steps are as follows:

- Model a complex urban environment with diverse sensors, weather conditions, mixed levels of autonomy and diverse scenarios. CARLA, a popular open-source simulator for autonomous driving research, will be utilised to model the environmental conditions and sensors.

- Within this simulated/testbed environment, the Dempster-Shafer (D-S) model [4] will be utilised to derive a belief function based on evidence i.e. local/cooperatively shared sensor readings. Unlike traditional Bayesian methods that characterise confidence of the situation state using probabilities, D-S characterises confidence of the situation state via different belief functions. A thorough analysis of the implication of diverse belief function rules will be conducted.

- The project will derive a belief framework that accounts for spatial and temporal correlations, environmental context, and evidential demands. This will build on works such as [5] and will devise novel belief rules that can weigh evidence based on contextual awareness that may impact the reliability or relevance of the evidence.

Références bibliographiques / Bibliography

[1] Malik, S.; Khan, M.J.; Khan, M.A.; El-Sayed, H. Collaborative Perception—The Missing Piece in Realizing Fully Autonomous Driving. Sensors 2023, 23, 7854. https://doi.org/10.3390/s23187854.

[2] Malik, S.; Khan, M.A.; El-Sayed, H. Collaborative autonomous driving—A survey of solution approaches and future challenges. Sensors 2021, 21, 3783. https://doi.org/10.3390/s21113783.

[3] SAE Levels of Driving Automation™ Refined for Clarity and International Audience. Available online: https://www.sae.org/blog/sae-j3016-update (accessed on 20 December 2022).

[4] Shafer, G. 1976. A Mathematical Theory of Evidence. Princeton, NJ: Princeton University Press.

[5] A. Saad, N. Bangalore, I. Kurzidem and P. Schleiss, "On Perceptual Uncertainty in Autonomous Driving under Consideration of Contextual Awareness," 2022 6th International Conference on System Reliability and Safety (ICSRS), Venice, Italy, 2022, pp. 387-393, https://doi.org/10.1109/ICSRS56243.2022.10067641.

Profil demandé / Applicant profile

Students with a master's degree in one of the following domains: computer science or telecommunication, or related degree e.g. Electronic/Electrical engineering.

Expected skills:
- Knowledge of wireless/cellular networks, with a particular focus on 5G technologies, connected vehicles, C-V2X.
- Knowledge of AI is not mandatory but will be considered positively for the application.
- Good knowledge of mathematical modelling.
- Good programming skills (C/C++, Python), computer graphics (GPU).
- Excellent communication and writing skills in English.

Preferred selection criteria:
- Excellent academic results.
- Good interview.
- Good oral skills and the ability to articulate technical concepts clearly and concisely.
- English and French speaking and writing.

Personal characteristics:
- Motivated, enthusiastic, and proactive.
- Ability to lead and direct your own research while taking on board suggested guidance.
- Good relationship, open mind.

Financement : MESRI Etablissement

Dossier à envoyer pour le / Deadline: **June 30, 2024**
Début du contrat / Start: **Octobre 1st, 2024**
Salaire mensuel brut / Monthly gross salary: **1975€**

Direction de la thèse:/ **Thesis Supervisor**

BAALA Oumaya / oumaya.baala@utbm.fr

Encadrement de la thèse : **co-directeur(s) et co-encadrant(s)**

O'DRISCOLL Aisling / Co-supervisor / aisling.odriscoll@ucc.ie
MABED Hakim / Co-supervisor / hakim.mabed@univ-fcomte.fr

Applicants are invited to submit their application to the PhD supervisors.
Application must contain the following documents:

- CV
- Cover letter
- At least 1 reference letter