PhD Offer – Safer Tram Driving Project

Working Title: Real time train driver state estimation using observers and data fusion techniques.

Supervisors:

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Work Organisation: Université Polytechnique Hauts-De-France, LAMIH UMR CNRS 8201.

City: Valenciennes.

Industrial collaborations:

- STRMTG: https://www.strmtg.developpement-durable.gouv.fr/
- OKTAL SYDAC: https://www.oktalsydac.com/ https://sogeclair.com/fr/simulation/simulation-ferroviaire
- FactHum France: https://facthum-france.fr/
- Keolis: https://www.keolis.com/

HOW TO APPLY:

- CV with contact details
- Bachelor and master transcripts (including list of courses with corresponding grades) for all the university years
- A summary of (or an e-link to) your master thesis
- Name and email of two references

CONTEXT

Tramways are an attractive form of surface mass transit, offering a high passenger flow, a safe solution and a clean alternative (electric power) to other modes of urban transport, such as cars or buses. However, this multiplicity of players in the tramway's traffic zone makes driver's task very demanding. Anticipation is the key to safety in urban visual driving, as the stopping distances of railway equipment are very long and obstacle avoidance is impossible. This makes the driver state at the core of the safety of the train, as he/she must be constantly attentive to prevent any risk of collision with third parties, whether moving or stationary, in a context where the field of view is sometimes severely reduced (masking by buildings, street furniture, signs, etc.).

This is the focus of the SaferTramDriving project: to propose and to develop innovative solutions in the field of driver state monitoring and driver assistance.

OBJECTIVES

The perceptual and cognitive workload of tramway drivers can be high, with a strong impact on vigilance (affected by cognitive and physical fatigue) and attention (concentration), which in turn can affect driver performance. In performing the driving task, there is therefore an optimal workload range within which the driver can maintain good performance over a longer period of time. Thus, the objective is to keep the driver's workload in an optimal range, using an advanced driving assistance system (ADAS) that self-adapts in real-time. Doing so requires to:

- estimate the driver state
- estimate the task demands to cope with the situation in the current driving environment.
- determine the best way to assist the driver by changing the requirements of the driving task in order to keep the driver in the optimum performance zone.

To ensure the efficiency of the system elaborated regarding the need of safety improvement, an important part of the project will be dedicated to prototype and evaluate this system. The evaluation will be carried out with a significant number of professional tramway drivers coming from different French networks, using a demonstrator developed as part of the project and based on an existing full-scale tramway simulator PSCHITT-Rail [1].

The PhD topic will be mainly around the problem of driver monitoring, in order to continuously inform the assistance system of the driver's state. The assistance system design will be the topic of a second PhD in the project, so interaction and "cross-validation" of the results are required.

METHODOLOGY

Assessment of the driver state is based on a combination of experience-based knowledge (on human behaviour and cognition) and a detailed consideration of the mechanisms underlying action decisions and information gathering in tramway driving.

To implement this model, relevant data will be collected during driving experiments on a full-scale tramway simulator, such as driver's actions, gaze direction, facial or postural data. Other data sources could be considered as well, measured or derived using observer-based techniques [2], such as unknown input observers.

Models and data will serve to reconstruct in real time models characterizing the driver's state and to develop algorithms allowing the estimation of his/her state (physical and emotional state, attention, etc.) without interference with the operational task. The goal is to produce some synthetic and robust indicators regarding the driver state.

To carry out this task, data fusion mechanisms will be developed, with mitigation of measurement and estimation uncertainty. Probabilistic approaches may be employed such as Bayesian Networks algorithms at decision level, and possibly Kalman filters for continuous data fusion. Considering the complexity of driver's state and interactions, along with the driving protocols, advanced hybrid modelling techniques might be appropriate, such as Hidden Markovian Models combined with more classical analytical equations [3] [4]. Processing multiple discordant information from available sources will be a non-trivial issue. It will be necessary to estimate the context and proceed to disambiguation which will lead to the development of a consensus seeking distributed algorithm for tramway driver's state estimation [4] [5].

MAIN TASKS AND SCHEDULE

- Literature review: Driver models, Observer Design, Data Fusion, Decision related mathematical frameworks.
- Modelling: Driver modelling considering vehicle and environment interaction. Both high level (cognition) and low level (procedures, actions) abstraction levels are involved.
- Experimentation: involvement in data acquisition preparation, and experimental tests.
- Design: Design of the appropriate algorithms for data fusion sensor level and feature level. Driver's state observer design. Decision algorithm design. Awareness of the assistance system constraints in the design.
- Validation: "Cross-validation" of the monitoring system and the assistance system. Validation of the algorithms in simulation and in real time experimental tests on the PSCHITT-Rail platform.

REFERENCES :

[1] PSCHITT-Rail platform https://www.uphf.fr/lamih/plateformes/mobilite-autonome/pschitt-rail

[2] T. M. Guerra, D. Berdjag, P. Polet, and A.-T. Nguyen, "Toward a Cooperative ADAS for Train Driving based on Real-Time Human Parameters and Delay Estimation," in *Proceedings of the 22nd IFAC World Congress*, Yokohama, Japan, 2023.

[3] D. Berdjag, F. Vanderhaegen, A. Shumsky, and A. Zhirabok, "Abnormal operation diagnosis in human & Machine systems," in *2015 10th Asian Control Conference (ASCC)*, Kota Kinabalu: IEEE, May 2015, pp. 1–6. doi: 10.1109/ASCC.2015.7244498.

[4] Rekabi, M. M., & Liu, Y. (2020). A Hybrid Analysis Method for Train Driver Errors in Railway Systems. In Soft Computing Methods for System Dependability (pp. 176-202). IGI Global.

[5] Brandenburger, N., Naumann, A., & Jipp, M. (2021). Task-induced fatigue when implementing high grades of railway automation. Cognition, Technology & Work, 23, 273-283.