

Towards artificial intelligence-based rail driving assistance tools

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1 Introduction

The work presented in this paper is conducted as part of the Academics4Rail Project, funded by Europe's Rail, the new European partnership in the railway sector within the framework of the Horizon Europe research project. The aim of Academics4Rail is to propose driver assistance systems for railway driving. In the first section, we will be looking at degrees of automation, in order to propose additional levels of progressive driver assistance. We will then take a taxonomy of driving activities to extract the tasks that need to be automated, and finally we will study the possibilities offered by the integration of Artificial Intelligence in the context of rail driving assistance.

2 Grades of Automation

Grades of Automation (GoA) define the allocation of actions between the driver and the rail systems. [1].

- **GoA-0** :Manual control only, without automatic protection device.
- **GoA-1** :Manual operation with automatic protection. The automated systems concern compliance with speed limits and danger signals (ATP), in-cab signal repetition (ERTMS) and VACMA.
- **GoA-2** :Train semi-autonome : Semi-autonomous train : the driver retains final authority over all systems, while assistance tools can act only under the driver's supervision (ATO).
- **GoA-3** :Driverless train : no driver on board, the train attendant is responsible for opening and closing the doors, as well as detecting and managing emergencies.
- **GoA-4** :Autonomous train. The train is fully automated, under the supervision of the Central Control Station.

In the Figure 1), levels 2 and 3, systems take over part of the tactical and operational management. Between levels 2 and 3, there is a transfer of authority from man to machine. This transfer has an impact on user safety and legal accountability in the event of an accident. Other scales exist in the literature to measure the level of automation of systems, for example the work of Endsley and Kaber[2],and Fereidunian[2]. These levels are intermediate between levels 2 and 3, to manage the transfer of authority and the increase in competence of the automated system. Two additional levels are proposed. They enable a natural transition from level 2 to level 3. Strategic tasks remain the responsibility of the driver. In order to be acceptable to drivers,[3], , the system must be designed in such a way that the driver retains final authority. In addition, the driver must understand the system [3]. At level 2.1, the system can act autonomously, for actions concerning its motion, but the driver remains active and retains authority over the supervision of the train's movement in its environment. The system enhances the driver's

	Niveaux	Opérationnel	Opérationnel	Tactique	Tactique	Stratégique
Grades of Automation	Tâches de conduite	Régulation de vitesse	Départ / arrêt en gare	Surveillance de l'environnement	Fermeture / ouverture portes	Détection et gestion des urgences
GoA-0		Conducteur	Conducteur	Conducteur	Conducteur	Conducteur
GoA-1	ATP	Conducteur \ Système	Conducteur	Conducteur	Conducteur	Conducteur
GoA-2	ATP+ATO	Système \ Conducteur	Conducteur \ Système	Conducteur	Conducteur	Conducteur
GoA-2.1		Système \ Conducteur	Conducteur \ Système	Conducteur \ Système	Conducteur \ Système	Conducteur
GoA-2.2		Système \ Conducteur	Système \ Conducteur	Système \ Conducteur	Système \ Conducteur	Conducteur
GoA-3	Driverless	Système	Système	Système	Personnel de bord	Personnel de bord
GoA-4		Système	Système	Système	Système	Système \ Poste de Commande Centralisé

FIG. 1 – Proposed adaptation of automation levels
<https://www.overleaf.com/project/65e07a4e73af2e58ae9ce0cc>

situational awareness, helping him to anticipate his driving. The system can then acquire the skills it needs for level 2.2. At level 2.2, a transfer of authority takes place, and the driver becomes the system's assistant for driving and environment supervision tasks that the system cannot handle alone. Final authority remains in the hands of the driver. The main benefit of this new approach is that it makes it possible to develop a system that keeps the driver involved in the driving task. The driver can retake control at any time, his skills do not disappear, and he is better disposed to react when the system needs help in a new situation.

In TAB. 1, the operational and tactical tasks of the task taxonomy proposed as part of the Carbodine project [3] are presented.

	Operational	Tactical
CRITICAL	Speed regulation	Doors closure / opening Monitoring of driving environment
AUXILIARY	Accessories Power management	Departure / stopping at station
SIDE	Lighting Comfort systems	

TAB. 1 – decision-making levels for driving tasks

The critical tasks of speed control and environmental monitoring need to be automated. These tasks have already been automated separately in previous work, particularly in the context of energy saving. Auxiliary tasks such as accessories and power supply are requested by drivers. [3]. They want a level of automation comparable to that of their car. The support tasks Lighting and Comfort Systems are part of the operational tasks of driving and are therefore within the scope of the study.

3 Artificial Intelligence benefits

In the literature, work has already been carried out on the integration of artificial intelligence into railway driving assistance tools. Artificial intelligence has also been used for the visual monitoring of tracks, state that Deep Learning is the most powerful Artificial Intelligence technique for image processing. Numerous studies have been carried out into the use of AI in generating speed profiles to increase train energy efficiency, for example : Approximate Dynamic Programming [5] Machine Learning et Deep Learning [4] [5], reinforcement learning, [5] SVM], Huang et al [6] have proposed a logic-oriented approach using a fuzzy decision tree

to learn from the experience of human drivers. The 2 main arguments for the use of AIs in railway driving are the ability of Artificial Intelligences to improve in unknown situations [4] that will occur during rail driving, which meets the intended system operation at level 2.2. Artificial Intelligences are also capable of learning and memorizing human solutions to problems they have not been able to solve [4] which is how the system functions at level 2.1. Artificial intelligence is also capable of reconfiguring the model and adapting it to the situation.

4 Conclusion

Artificial intelligence seems a promising avenue for the development of new driver-centric rail assistance systems. The addition of automated functions requested by drivers could potentially increase the acceptability of these aids. Moreover, the introduction of intermediate levels gives the system time to learn, enabling a gradual transition from a train with a driver to one without.

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Références

- [1] L. Habib, O. Oukacha, et S. Enjalbert, « Towards Tramway Safety by Managing Advanced Driver Assistance Systems depending on Grades of Automation », IFAC-PapersOnLine, vol. 54, no 2, p. 227-232, 2021, doi : 10.1016/j.ifacol.2021.06.027.
- [2] M. Vagia, A. A. Transeth, et S. A. Fjerdings, « A literature review on the levels of automation during the years. What are the different taxonomies that have been proposed ? », Applied Ergonomics, vol. 53, p. 190-202, mars 2016, doi : 10.1016/j.apergo.2015.09.013.
- [3] J.-V. Merlevede, S. Enjalbert, F. Henon, A. P. Baños, S. Ricci, et F. Vanderhaegen, « Expectations of train drivers for innovative driving cabin », IFAC-PapersOnLine, vol. 55, no 29, p. 144-149, 2022, doi : 10.1016/j.ifacol.2022.10.246.
- [4] N. Besinovic et al., « Artificial Intelligence in Railway Transport : Taxonomy, Regulations, and Applications », IEEE Trans. Intell. Transport. Syst., vol. 23, no 9, p. 14011-14024, sept. 2022, doi : 10.1109/TITS.2021.3131637.
- [5] R. Tang et al., « A literature review of Artificial Intelligence applications in railway systems », Transportation Research Part C : Emerging Technologies, vol. 140, p. 103679, juill. 2022, doi : 10.1016/j.trc.2022.103679.
- [6] J. Huang, Y. Cai, J. Li, X. Chen, et J. Fan, « Toward Intelligent Train Driving through Learning Human Experience », in 2019 1st International Conference on Industrial Artificial Intelligence (IAI), Shenyang, China : IEEE, juill. 2019, p. 1-6. doi : 10.1109/ICIAI.2019.8850749.