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Name	Beneficiary Short Name	Details of contribution
Simon Enjalbert	UPHF	Document issue
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Table of Content

1 Summary of activities

Work Package 9 has started with the recruitment of Jean-Valentin Merlevede who is working at UPHF since October 1st 2023 and supervision with SUPSI has been initiated at this date. Unfortunately, no collaboration has been achieved with SNCF nor RAILENIUM during M1 to M24. However, a new industrial partner (ALSTOM Italy) has participated in several remote meetings (in March, June and December 2024) to discuss the opportunity of research challenges raised by the project. A 2 months visiting scholar has been organized at SUPSI for co-supervision of PhD activities. Partner has offered seminar and access to laboratory to increase AI knowledge of PhD student.

Scientific contributions (M1 to M24) can be summarized into two points:

1. State-of-the-art about key concepts. The step has consisted in identifying the main scientific advances about the development of ICT for train cabin, of train driving assistances, and of their impact on drivers' behaviours. The research has selected the disruptive supports that can be used for the PhD thesis and the driving tasks to be assisted on GoA.
2. Implementation of configurations of GoA integrating driving assistance and ICT. With regard to the outputs of the first step, this part of the thesis has developed models for assisting drivers and for monitoring them.

The lack of financial support has led partners to find external possibilities to organize long visiting scholar. Many student mobility calls have been answered successfully by M. Merlevede to reach this objective. The 2-months visiting scholar at SUPSI was financed by a French regional project and SUPSI funding. We cannot be sure that new visiting period will be organized till the end of the project.

A new contribution is now under investigation by PhD candidate. It concerns proposal for new ways to design and validate AI-based driving assistance. The models of the second step of the project could be used to propose new ways for designing and validating driving assistances in railway (M24 to M42).

2 Detailed planning of activities (M1 to M24)

List of activities related to Academics4Rail project and WP9:

- Kick-off Berlin 20230919
- Visio WP9 meeting #1 20231211
- Visio WP9 meeting #2 20240320
- General Assembly visio 20240321
- Nat. Conf. SAGIP: 20240530
- Visio WP9 meeting #3 20240626
- General Assembly Bilbao 20240917
- ~~Visio WP9 meeting #4 202410 *(cancelled after GA)*~~
- Int. Conf. MAIH: 20241120
- Visio WP9 meeting #5 20241209
- General Assembly visio 20250210
- ~~Visio WP9 meeting #6 202503 *(cancelled after GA)*~~
- Visio WP9 meeting #7 20250623
- General Assembly visio 20250916
- Visio WP9 meeting #8 20250916 ~~*(cancelled during GA)*~~
- Transbaltica 20250919
- Int. Conf. 'IFAC HMS' Beijing 20251103
- Visio WP9 meeting #9 202512 *(planned)*
- Visio WP9 meeting #10 202603 *(planned)*
- Visio WP9 meeting #11 202606 *(planned)*
- PhD defense WP9 meeting #12 202609

All WP9 and General Assembly (GA) Minutes of Meetings (including participants) are available online on A4R deposit.

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3 List of published papers

Articles published in International Conference.

1. MERLEVEDE J.-V., **ENJALBERT S.**, VANDERHAEGEN F., FLAMMINI F., LIU R., WETTIG A., ABRAMOVIC B., CHALKIA H. (**2025**). New definition of Grades of Operational and Tactical Automation in rail domain. *16th International Conference TRANSBALTICA 2025: Transportation Science and Technology. Accepted.*

This work proposes an extension of the traditional Grades of Automation (GoA) in order to allow both dedicated Operational and Tactical assistances. The contribution aims to reintegrate the driver into the train driving activity with the new Grades of Operational and Tactical Automation (GOTA) taking into account human involvement and driving skills. The GOTA Selector which helps the driver to be optimally engaged while driving by adapting the GOTA to the specific needs is then planned.

2. MERLEVEDE J.-V., **ENJALBERT S.**, VANDERHAEGEN F., FLAMMINI, F. (**2024**). Towards artificial intelligence based rail driving assistance tool. *International Conference on Mobility, Artificial Intelligence and Health 2024 (MAIH 2024)*, (DOI: 10.1051/itmconf/20246903005).

This work proposes additional levels of progressive driver assistance expanding the traditional Grades Of Automation (GoA) in order to allow both higher level of automation and keeping the driver involved in driving task at the same time. The second contribution is the Digital Co-Driver which aims to bring the driver back in the train driving activity with the new GoA defined before, taking into account human involvement and driving skills. This framework is made up of several modules, each of which addresses a specific issue arising from the increased level of automation. The Driver State and Performance Monitoring Module monitors the driver's involvement, situation awareness and performance. The Digital Adviser Module improves driver's situational awareness, and the Digital Teacher Module improves his/her driving skills and knowledge of the system. Finally, the Safety Manager ensures the system's compatibility with safety standards.

Articles or posters published in National Conference.

3. MERLEVEDE J.-V., **ENJALBERT S.**, VANDERHAEGEN F. (**2024**). Vers des outils d'aide à la conduite ferroviaire à base d'intelligence artificielle. 2eme Conference *SAGIP 2024 (HAL: 04541829v1).*

Les travaux présentés dans ce papier sont réalisés dans le cadre du Projet Academics4Rail, financé par Europe's Rail, qui est le nouveau partenariat européen dans le domaine ferroviaire créé dans le cadre du projet de recherche Horizon Europe. Le but d'Academics4Rail est de proposer des assistances aux conducteurs pour la conduite ferroviaire. Dans un premier temps, nous allons étudier les degrés d'automatisation pour proposer des niveaux supplémentaires qui correspondent à une assistance progressive à la conduite. Puis nous reprendrons une taxonomie des activités de conduite pour en extraire les tâches qui devront être automatisées et enfin nous étudierons les possibilités qu'offre l'intégration de l'"Intelligence Artificielle dans le cadre de l'assistance à la conduite ferroviaire.

4. MERLEVEDE J.-V., **ENJALBERT S.**, VANDERHAEGEN F. (**2025**). Nouveaux Grades Opérationnels et Tactiques pour l'Automatisation ferroviaire. Journée Régionale des Doctorants en Automatique (JRDA 2025) (HAL: hal-05123200v1).

Poster in French conference

5. MERLEVEDE J.-V., **ENJALBERT S.**, VANDERHAEGEN F. (**2024**). Towards artificial intelligence-based rail driving assistance tools. Journée Régionale des Doctorants en Sciences de la Mer et Automatique (JRDMA 2024) (HAL: hal-05115359v1).

Poster in French conference

4 List of submitted papers

Articles submitted for publication in Journal or in International Conference.

6. MERLEVEDE J.-V., **ENJALBERT S.**, VANDERHAEGEN F., (**2025**). Grades of Operational and Tactical Automation in rail domain for an Artificial Intelligence Driving Assistance System. *Cognition, Technology & Work. Under revision.*

This work proposes new additional levels of progressive driver assistance, extending the traditional Grades Of Automation (GoA) in order to allow both dedicated Operational and Tactical assistances. The second contribution is an Artificial Intelligence Driving Assistance System (AIDAS) that aims to reintegrate the driver into the train driving activity with the new Grades of Operational and Tactical Automation (GOTA) defined previously, taking into account human involvement and driving skills. The framework of Digital Co-Driver (DCD) is comprised of multiple monitoring and modules, each addressing a distinct issue arising from the augmented level of automation. The Driver State, Driving Performance and Environmental Monitoring provide indicators of global driver involvement to maintain a high level of performance in manual driving and to deal with system failures. The GOTA Selector Module then helps the driver to be optimally engaged while driving by adapting the GOTA to the specific needs. Finally, the Driver Companion Module learns about the driver's preferences and needs to adapt the assistance and help the driver to improve their own driving skills.

7. MERLEVEDE J.-V., **ENJALBERT S.**, VANDERHAEGEN F., FLAMMINI, F. (**2025**). Designing an Artificial Intelligence Driving Assistance System (AIDAS) for train drivers. *16th IFAC Human – Machine Systems 2025. Submitted.*

This paper propose system in order to promote a new task sharing approach for railway driving. The system depends on three monitoring modules for evaluating the driver's condition, driving performance, and the driver's instantaneous and anticipated workload, and two output modules to compute, compare and select the best approach. Initially, data on the driver and the train driving parameters are collected and utilised to generate indicators. Finally, the algorithms to propose a distribution of train driving tasks is analysed in relation to the indicator that has been previously calculated. The objective of the task distribution is twofold: firstly, to optimise the driver's workload, and secondly, to modify the distribution when the driver is under or overloaded. The algorithm has the capacity to enhance the driver's performance and skills, or to adapt the driver's workload.

5 Annexes

Full text of articles or posters published:

1 New definition of Grades of Operational and Tactical Automation in rail domain.
2 Towards artificial intelligence based rail driving assistance tool.
3 Vers des outils d'aide à la conduite ferroviaire à base d'intelligence artificielle.
4 Nouveaux Grades Opérationnels et Tactiques pour l'Automatisation ferroviaire.
5 Towards artificial intelligence-based rail driving assistance tools.

New definition of Grades of Operational and Tactical Automation in rail domain

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Abstract. The present paper puts forward a proposal for an extension to the conventional Grades of Automation (GoA) with a purpose of facilitating both dedicated operational and tactical assistance. The contribution aims to reintegrate the driver into the train driving activity with the new Grades of Operational and Tactical Automation (GOTA). The proposal of GOTA is intended to provide train drivers with the option of varying the level of automation over time. Furthermore, they will facilitate the breakdown of the assistance level into tactical and operational tasks. This breakdown will be according to the specific characteristics of the driver and a variety of criteria, taking into account human involvement and driving skills. The GOTA Selector which helps the driver to be optimally engaged while driving by adapting the GOTA to the specific needs is then planned.

Keywords: Automation, Railway, Human-Machine Systems, ADAS

1 Introduction

Given the advances in autonomous technology, readers may feel that our position is outdated and that the future of rail travel lies with autonomous trains. We would therefore like to draw readers' attention to the presence of human pilots on commercial aircraft, which have been capable of flying without them for several years now. Together, we will explore the reasons that have led us to propose a new approach to train automation, which aims to enable a new method of task distribution to facilitate collaboration between the train and its driver. The extant literature has demonstrated that this transition has a detrimental effect on operators' workload, situational awareness and reaction time [1]. Studies have shown that using highly automated systems in train driving has had a negative impact on situational awareness and the ability of operators to regain control in the event of a system failure [2]. A lack of information or training, as indicated by research on Advanced Driver Assistance Systems (ADAS), results in a decrease of driving skills and sub-optimal performance [3]. This system will make it possible to maximise the contribution of our two agents on board, which are the human driver and the autonomous driving agent. The next stage of the study will be to examine Grades of Operational and Tactical Automation (GOTA) and ascertain how they differ from the more familiar Grades of Automation (GoA). This will demonstrate the advantages of this innovative approach to the distribution of tasks between human and artificial driving agents.

2 Balancing Human and Machine: A Shared Control Approach

Following the integration of Human-Machine Systems, the focus has shifted to the distribution of tasks between humans and automated systems. Two distinct areas have been the subject of detailed analysis in these studies. The first of these focused on the level of assistance provided, while the second concentrated on the consequences of this level on both parties involved.

In the process of designing automated systems, it is imperative to consider the repercussions that assistance functions have on the automated agent, particularly with regard to its integration and the operator's workload. The latter decreases as a consequence of the fundamental transformation in the nature of assistance functions. A variety of scales have been developed for the purpose of measuring the level of automation of systems [4]. It has been observed that certain users, manufacturers and administrative regulations have temporarily rejected proposed increases in the level of assistance, which would have involved a change in the driver's position on board by cabin crew. These automations, which resulted in an elevated automation level, precipitated a transition in the driver's role from an active to a supervisory position within the operation of the train managed by an automated system.

Several academic research have been conducted to emphasise the repercussions of these automation measures on human operators [5]. A significant proportion of the literature has underscored the challenges encountered by operators and drivers in maintaining an active supervisory role when overseeing such highly automated systems. The extant literature has demonstrated that the transition from manual system to highly automated system has a deleterious effect on operators, in terms of both their workload [1] and their situational awareness. This has been shown to result in a decrease in driver involvement and a substantial increase in reaction time [3]. As indicated in [6], drowsiness has also been observed. In order to circumvent these issues and ensure transport safety, it is imperative to closely monitor the driver's engagement in driving activities and adapt the degree of automation in these diverse tasks accordingly, thereby sustaining the driver's attention and involvement.

Numerous studies have previously indicated that the implementation of highly automated systems in train driving has exerted a detrimental effect on situational awareness [7] the capacity of operators to regain control in the event of a system failure [8]. In order to enhance the level of automation, it is imperative to consider the driver's level of situational awareness. Research on Advanced Driver Assistance Systems (ADAS) indicates that a lack of information or training among drivers results in a decrease of driving skills, as evidenced by the Nordhoff study [9], and to sub-optimal performance due to the driver's unfamiliarity with the operation of the automated system, as elucidated by the Endsley study [10]. In order to provide appropriate training, it is necessary to be constantly aware of the driver's behaviour. The objective is to ensure the continuity of collaboration in the event of a decline in skills.
In light of the considerable risks involved for both the driver and the train, the integration of artificial intelligence in the railway sector necessitates a deep understanding of human factors, as well as the interplay between automation and the driver. This approach is imperative for effective driver integration and safety, ensuring seamless operation for both passengers and railway equipment.

3 From GoA to GOTA

The grade of automation is comparable to the SAE Levels of Driving Automation in the context of road transport [11]. Like their road transport counterpart, GoAs are used to allocate tasks related to driving tasks between assistance systems and the driver. The GoA have defined an international standard ($IEC62290 - 1$) for the development and compatibility of train driving assistance and automated train control systems. They integrate Automatic Train Protection (ATP) and Automatic Train Operation (ATO) systems.

3.1 Grades of Automation

As shown in the Figure 1, system in GoA-2 and GoA-3 take responsibility for some of the management of operational and tactical tasks ([12]). This transition denotes a transfer of authority from human operators to automated systems. This change raises questions about the role of the driver. The transition has seen the driver's traditional role as the primary controller of the locomotive change to that of a supervisor overseeing a highly automated system. To make this transition smoother, we have proposed extending the GoAs by adding two additional transition levels, expending GoA2. The aim of these levels is to enable the introduction of rolling stock that is both suited to human driving requirements and capable of autonomous driving at different levels of supervision. From a system perspective, it allows the technology to mature while relying on a human operator to mitigate any potential problems. From a human perspective, this solution makes drivers' jobs easier by offering them a system designed for collaboration that is capable of adapting to the driver. Since the driver retains control of the system, the driver retains authority over the system.

	Levels	Operational	Operational	Tactical	Tactical	Strategical
Grades of Automation	Driving tasks	Speed regulation	Departure / stopping at station	Monitoring of driving environment	Doors closure / opening	Detection and management of emergencies
GoA-0		Driver	Driver	Driver	Driver	Driver
GoA-1	ATP	Driver \ System	Driver	Driver	Driver	Driver
GoA-2	ATP+ATO	System \ Driver	Driver \ System	Driver	Driver	Driver
GoA-2.1		System \ Driver	Driver \ System	Driver \ System	Driver \ System	Driver
GoA-2.2		System \ Driver	System \ Driver	System \ Driver	System \ Driver	Driver
GoA-3	Driverless	System	System	System	Train attendant	Train attendant
GoA-4		System	System	System	System	System \ Operational Control Center

Fig. 1. Extension of GoA-2

In Figure 1, at the grade 2.1, the driver is still responsible for monitoring the environment in which the train is operating, but the train is capable of moving under the driver's supervision and provides the driver with information about the situational awareness helping to improve anticipation. Regarding grade 2.2, the driver's role transforms significantly, becoming supervisory. Consequently, the driver assumes the role of supervisor for driving and environmental monitoring tasks that the system cannot perform independently. The driver retains ultimate authority for decision-making. The proposed framework is designed to ensure the continued engagement of the driver in the driving task. The proposal to extend GoA-2 to three sub-grades requires the classification of different train driving tasks. This classification must coordinate the tasks and the grade at which they will be automated. The operational and tactical tasks of the task taxonomy proposed as part of the CARBODIN project ([13]) are presented in Table 1.

There is a relationship between the GoA and the distribution of driving tasks

Table 1. Driving tasks distribution regarding authors taxonomy and decision making levels

	Operational GoA-1	Tactical GoA-2 to GoA-4
CRITICAL	**Speed regulation**	**Doors closure / opening** **Monitoring driving environment**
AUXILIARY	Accessories Power management	**Departure / stopping at station**
SIDE	Lighting Comfort systems	

proposed by CARBODIN. The operational task of speed regulation is automated in GoA-1, while tactical tasks are automated from GoA-2 to GoA-4. In our research, we will consider tasks requiring a deliberate cognitive process to be tactical or strategic tasks. Strategic tasks and GoA-4 will not be studied in this work because their automation only concerns fully autonomous trains. This classification allows driving tasks to be allocated between the different GoA. Speed regulation tasks must be automated, but their automation is not the subject of our research. Critical tasks such as speed control and environmental monitoring must be automated. These tasks have already been automated separately in other studies, particularly in the context of energy savings. Drivers have indicated that they prefer the integration of additional tasks, including accessories and power supply. Assistance tasks, namely lighting and comfort systems, are considered integral components of the operational tasks associated with driving and, as such, fall within the scope of the study. A comprehensive review of the literature on train driving automation indicates that the delineation of tactical and operational tasks reveals a limitation of GoA. Indeed, the automation of tactical tasks within the GoA framework implies the automation of operational tasks, whereas drivers express a preference for tactical assistance. A new system allowing for automation tailored to each driver should therefore be proposed.

3.2 Grades of Operational and Tactical Automation

		Levels	Operational	Tactical
Operational and Tactical Automation	Grades of Automation	Driving tasks	Speed regulation Departure / stopping at station	Monitoring of driving environment Doors closure / opening
0.0	GoA-0		Driver	Driver
0.1			Driver	Driver \ System
0.2			Driver	System \ Driver
0.3			Driver	System
1.0	GoA-1	ATP	Driver \ System	Driver
1.1			Driver \ System	Driver \ System
1.2			Driver \ System	System \ Driver
1.3			Driver \ System	System
2.0	GoA-2	ATP+ATO	System \ Driver	Driver
2.1	*GoA-2.1*		System \ Driver	Driver \ System
2.2	*GoA-2.2*		System \ Driver	System \ Driver
2.3			System \ Driver	System
3.0			System	Driver
3.1			System	Driver \ System
3.2	GoA-3	Driverless	System	System \ Train attendant
3.3	GoA-4		System	System

Fig. 2. Grades of Operational and Tactical Automation (GOTA)

The GoA is a fixed system whose configuration is determined during the design of the rolling stock, while the new Grades of Operational and Tactical Automation (GOTA) illustrated in Figure 2 are levels that adapt to the driver and their condition. The utilisation of the GoA as the sole representative of a train's automation level entails the exclusion of numerous solutions. The GoA's proposed grouping is not subject to review here. However, the GOTA unifies and standardises all the assistance proposed in the train. This will facilitate the incorporation and management of Driver Advisory System (DAS) tools, which assist drivers in tactical planning, into the assessment of the requisite level of assistance. This methodology will make it easier to take into account the specific characteristics of each driver, thereby adapting their workload and assigning them tasks that correspond to their strengths or areas for improvement. The use of this GOTA approach will facilitate the identification of relevant assistance measures.

The GoA system has been designed with a specific hierarchy of automation, prioritising operational tasks before tactical tasks. However, there are already tactical assistance systems, the DAS system, in place on trains, though these are not factored into the GOA levels. It was not considered either that a driver would want to delegate the management of stops in stations to the system while retaining traction control. However our objective is to facilitate a consolidated support system, thereby ensuring that a unified framework is capable of overseeing all support mechanisms. That is why GOTA has been developed to provide a framework for a more nuanced approach to defining the levels of assistance required for each of the two groups of tactical or operational tasks, independently of each other. The unique attribute of GOTA is its capacity to furnish assistance scenarios that are not encompassed by GoA, particularly with regard to skills management and driver involvement in driving supervision. The provision of a unifying structure that enables distinct levels of autonomy to be seamlessly transitioned between, while accommodating diverse assistance modalities and control systems, is expected to mitigate the necessity for subsequent augmentations. There are different paradigms for task distribution, and their impact on driver performance and well-being will need to be studied. This approach facilitates the maintenance of a simple and organised structure that can evolve independently in each area, thus avoiding additions that are difficult to integrate. This will enable a single scheduler system to adapt to different situations, hardware and software, to adapt to national regulations, legislation, standards, restrictions, or in relation to advances made by manufacturers, the condition of equipment, the complexity of networks, or in relation to personnel based on their training, skills, and experience.

4 Perspectives

In the context of ongoing initiatives to enhance rail safety and efficiency, a novel assistance system is set to be introduced. The GOTA framework will be integrated into this railway driving assistance tool with the objective of incorporating human factors into its design. The human factors and the adaptation of assistance systems, which were the subject of the first part of this article, are taken into account to optimise the performance of the Human-Machine System by avoiding the inherent pitfalls of supervisory tasks. The system has been designed to assess and mitigate the impact on the driver in real time, thereby ensuring that they are able to regain control in the event of a critical failure. Instead of a predetermined level of assistance at the system's initiation, the Dig-

ital Co-Driver (DCD) will offer assistance levels that are adapted to the driver's current status. This will include performance and state indicators that continuously assess the driver and their condition. The system must be designed to efficiently adjust the level of assistance to the driving task.
As part of the assessment and monitoring of the system's impact on the driver, it is essential to evaluate the following three indicators: The first indicator assesses the driver's cognitive state and their involvement in the driving process. We used several biomarkers to monitor changes in the driver's condition to estimate the driver's workload, vigilance, and situation awareness. This proposed biofeedback system aims to gather several non-invasive markers and combine them to provide reliable tracking of the driver without disturbing them. The second indicator aims to assess driver performance. Performance will be compared both to the theoretical optimum achievable results and to previous driver assessment results. The purpose of this evaluation is to ensure that the competence of the drivers does not deteriorate due to repeated use of the assistance systems. The third indicator assesses the environmental conditions in which the train is operating. It takes into account various criteria, such as the complexity of the track, stops and weather conditions, to estimate the workload that the environment will generate for the driver.
Accounting for these different indicators aims to enable the rail driving assistance tool to detect and mitigate the multiple negative consequences of automation in order to preserve the best of both machines and humans. It will then be possible to assess the relevance of the assistance strategies deployed in real time, but is also used in the longer term to generate a new assistance strategy adapted to the anticipated load. The system will be capable to determine how the driver is affected by the current task and to assess their need for assistance with future tasks. The recording of this data will enable the driver to be offered driving phases and knowledge reviews to maintain their driving ability at a level that allows them to detect any problems with the automated systems and to be able to react.

5 Acknowledgments

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6 Disclaimer

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Towards artificial intelligence based rail driving assistance tool

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Abstract. This work proposes additional levels of progressive driver assistance expanding the traditional Grades Of Automation (GoA) in order to allow both higher level of automation and keeping the driver involved in driving task at the same time. The second contribution is the Digital Co-Driver which aims to bring the driver back in the train driving activity with the new GoA defined before, taking into account human involvement and driving skills. This framework is made up of several modules, each of which addresses a specific issue arising from the increased level of automation. The Driver State and Performance Monitoring Module monitors the driver's involvement, situation awareness and performance. The Digital Adviser Module improves driver's situational awareness, and the Digital Teacher Module improves his/her driving skills and knowledge of the system. Finally, the Safety Manager ensures the system's compatibility with safety standards.

1 Introduction

Railway driver interfaces have undergone profound changes to adapt to all the systems that have gradually been incorporated into trains. The CARBODIN project [1] proposed to redesign and rethink the organization of the cabin by integrating both new systems and new interactions from the earliest design stages. This approach has highlighted drivers' interest in innovative interfaces based on new technologies, such as haptic, gesture and voice, which currently have no place on trains. We are now looking to extend this work by studying how Artificial Intelligence (AI) can be integrated into train driving. Various definitions of AI exist in the literature; in this paper, we consider AI to be all technologies that enable the transition from an automated system to an autonomous system capable of adapting to its environment. The aim of Academics4Rail is to propose driver assistance systems for railway driving.

In the first section, degrees of automation in railways sector, in order to propose additional levels of progressive driver assistance, are detailed. A taxonomy of driving activities to extract the tasks that need to be automated is proposed. The possibilities offered by the integration of the concept of a Digital Co-Driver (DCD) is then studied in the context of rail driving assistance. The DCD is an assistance tool framework which is created with the aim of maintaining the driver in the loop of controlling highly automated vehicles. The DCD is structured into modules, each covering one of the requirements identified during the conceptual phase. The Driver State and Performance Monitoring Module monitors the driver's involvement, situation awareness and performance to tune the behavior of the DCD according to the driver. The Digital Adviser Module improves driver's situational awareness by providing him relevant information regarding to the driving condition. The Digital Teacher Module selects the combination of methodological approach and interface best suited by the driver depending on learning abilities. It improves driver's driving skills or, when the driver performs better than the system, updates the artificial agent driving abilities. Finally the Safety Manager ensures the system's compatibility with safety standards. In the last section, we present the development steps we planned do achieve the DCD implementation.

2 Automating rail operations

In a Human-Machine Systems, the shared control of tasks between the human operator and an automated agent has been the subject of numerous studies. The aim of these studies was not only to determine levels of assistance, but also to identify the consequences of these levels of assistance for the system and the operator. One of the main issues studied in the design of automated systems is the impact of the addition of assistance functions on driver involvement and workload. Grades of Automation (GoA) define the distribution of driving tasks between the driver and the system, based on the capabilities of the automated driving agent [2].

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	Levels	Operational	Operational	Tactical	Tactical	Strategical
Grades of Automation	Driving tasks	Speed regulation	Departure / stopping at station	Monitoring of driving environment	Doors closure / opening	Detection and management of emergencies
GoA-0		Driver	Driver	Driver	Driver	Driver
GoA-1	ATP	Driver \ System	Driver	Driver	Driver	Driver
GoA-2	ATP+ATO	System \ Driver	Driver \ System	Driver	Driver	Driver
GoA-2.1		System \ Driver	Driver \ System	Driver \ System	Driver \ System	Driver
GoA-2.2		System \ Driver	System \ Driver	System \ Driver	System \ Driver	Driver
GoA-3	Driverless	System	System	System	Train attendant	Train attendant
GoA-4		System	System	System	System	System \ Operational Control Center

Figure 1. Proposed extension of Grades of Automation (GoA)

- **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:**Semi-autonomous train : 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, GoA-2 and GoA-3, systems take over part of the tactical and operational management. Between GoA-2 and GoA-3, there is a transfer of authority from human to machine. This transfer has an impact on user safety and legal accountability in the event of an accident. Furthermore, the first implementations of GoA-2 trains raise questions about the transformation of the driver's role. Driver has gone from being the locomotive's active controller to the supervisor of a highly automated system. In the literature, there is a great deal of research on the difficulty for operators to remain active in a supervisory task. Other scales exist in the literature to measure the level of automation of systems, for example the work of Endsley and Kaber[3], and Fereidunian[3]. Upgrading from GoA-2 to GoA-3 means replacing the driver on board with train attendants. This does not yet seem acceptable to some users and manufacturers. It is therefore necessary to propose additional GoA that allows us to increase the grade of automation while keeping a driver on board. These grades are intermediate between GoA-2 and GoA-3, to manage the transfer of authority and the increase in competence of the automated system. They also enable the development of a human-centered system to mitigate the negative effects of high grades of automation on driver attention. They enable a natural transition from GoA-2 to GoA-3. Strategic tasks remain the responsibility of the driver. In order to be acceptable to drivers,[1], the system must be designed in such a way that the driver retains final authority. In addition, the driver must understand the system [1]. At GoA-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 situational awareness, helping him to anticipate driving tasks. The system can then acquire the skills it needs for GoA2.2. At GoA-2.2, The controller's role undergoes a major transformation, moving from active participation to a supervisory role, so the driver becomes the system's supervisor for driving and handling environment supervision tasks that the system cannot handle alone. Final authority remains in the hands of the driver. This new grade can be used in situations where the driver does not have sufficient reaction time to complete the driving task while ensuring passenger safety. For example, if distances between trains are reduced to cope with increasing customer volumes on a network that has no room to grow. 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 take control back any time, keeping skills up-to-date, and better disposed to react when the system needs help in a new situation.
Now that we've proposed two new grades, GoA-2.1 GoA-2.2 for railway driving, the question arises as to which tasks we're going to automate. To answer this question, we'll compare a taxonomy of driving tasks with the GoA. In Table 1, the operational and tactical tasks of the task taxonomy proposed as part of the CARBODIN project [1] are presented.

A correlation between task taxonomy from CARBODIN and decision making levels can be observed. Indeed, for GoA-1 only the operational task of speed regulation is automated, whereas from GoA-2 to GoA-4, the automated functions are at tactical decision making level. Strategic tasks are not covered before the GoA-4, out of the scope of our study. This correlation makes it possible to determine the grade at which the tasks in the different categories are available to be transferred to the system by the driver. 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

Table 1. Driving tasks distribution regarding authors taxonomy and decision making levels

	Operational GoA-1	Tactical GoA-2 to GoA-4
CRITICAL	**Speed regulation**	**Doors closure / opening** **Monitoring driving environment**
AUXILIARY	Accessories Power management	**Departure / stopping at station**
SIDE	Lighting Comfort systems	

saving. Auxiliary tasks such as accessories and power supply are requested by drivers. [1]. 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.
With the changes in the driver's role arising from the higher GoA implementation, the driver moves from an active role in controlling the vehicle to a role as supervisor of the automated system operating the train. This shift has been extensively studied in the literature, in view of the consequences it has on the human operator [4]. In the literature, researchers have argued that this transition negatively affects the human operator's workload [5], as well as situation awareness. This reduces involvement in the driving process and considerably increases reaction time [6]. In the worst case, this can even lead to drowsiness [7]. In order to maintain safety and enable the driver to regain control of the system in the event of an unforeseen event, it is therefore important to monitor the driver's involvement in the driving task, and to adapt the distribution of tasks to reduce the risk of the driver getting out of the loop. Despite its importance in railway driving, previous studies have pointed a negative impact of highly automated systems on situation awareness [8] and the operator's ability to rebuild his/her situational awareness in the event of loss of automated functions [9]. So, if we want to increase the grade of automation, we need to take the driver's situational awareness into account. Finally, according to studies on car driving, driving with ADAS when the driver is not properly informed and trained not only reduce drivers' driving skills [10], but also lead to counter-performance due to the driver's lack of knowledge of how the automated system works[11]. It is therefore appropriate for the automated system integrated into the train to monitor the driver's performance and train him/her to collaborate with or in the event of a skill loss. In light of these potential risks for the driver and/or train, the implementation of Artificial Intelligence in trains requires us to take into account human factors and the impact of our system on the driver, in order to optimize involvement and safety, as well as that of passengers and rolling stock.

3 Digital Co-Driver

In the literature, there are numerous studies of railway driver assistance systems, mainly aimed at improving network management [12, 13] and energy efficiency [14, 15]. However, the majority of these studies do not take the human factor into account, or merely check that the driver is able to apply the system's instructions with sufficient speed and precision for the system to be effective. In the same time, there are already articles highlighting the negative impact of these systems on the driver condition [5, 6, 8]. We therefore need to propose an assistance system that put human back in the loop. To counterbalance the potential undesirable effects of increasing levels of automation in the railway sector, the Digital Co-Driver(DCD) is designed to focus on keeping the driver active in the driving task. This approach is justified by recent work in the field of semi-autonomous vehicles [16], but also in industry, where operators interact with increasingly intelligent robots.In addition to improving the safety and performance of the Human-AI Team, the Digital Co-Driver also addresses the issues of operator well-being that are at the heart of the Industry 5.0 model [17]. One of the most important issues in achieving an AI-based system that is safe for both driver and user is the Black Box problem. This problem of artificial intelligence-based systems, which implies that the system has become so complex that even the designer cannot predict its behavior [11], makes Human-Artificial Intelligence cooperation unpredictable.
In order to build an efficient collaboration between the DCD and the driver, human is put back into the loop to ensure the DCD adaptation to various human behavior like cooperation, competition, or non collaboration. It should be able to achieve a better driver involvement in driving activities regardless of the driver's attitude towards the system. The Digital Co-Driver, presented in Figure 2, consists of 4 main modules, each of which is designed to address one of the bottlenecks slowing down the integration of artificial intelligence-based systems in trains. The Driver Monitoring System mainly addresses problems of driver involvement in the driving task. The Digital Co-Driver uses Hybrid Human-Artificial Intelligence approaches [18] to improve Human-Artificial Intelligence by implementing transparency and explainability [16].Neuro-Symbolic artificial intelligence seems a promising solution to enable artificial intelligence system collaboration with human. This field mixes logic programming and deep

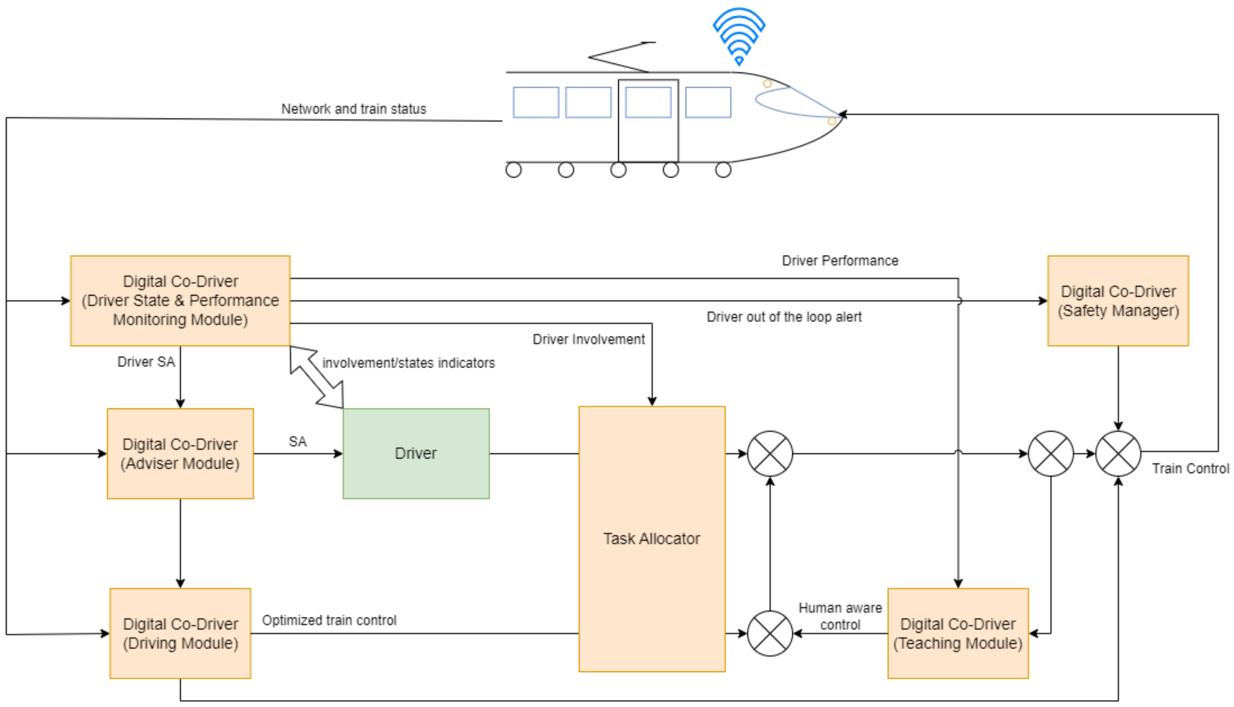

Figure 2. Digital Co-Driver operating diagram

learning methodology for a better human understanding of the artificial agent. A model proposed by Vanderhaegen [19] to divide tasks between a human actor and an assistance system, according to the triplet (Competence, Availability, Possibility-to-act (CAP)), is used by DCD at early learning stages to select the correct agent for the ongoing task. The Digital Advisor provides the driver with all the necessary and relevant information to enable him or her to perform according to energy efficiency and safety criteria. The Digital Teacher determines the most appropriate teaching method for the driver. And finally, the Safety Manager ensures that the decisions taken by the Human-AI team comply with safety standards, avoiding costly developments for manufacturers. To ensure the safety of the Digital Co-Driver, its actions on the train have to pass through a safety manager who is compatible with the standards that apply to railway safety and makes the implementation of artificial intelligence possible [20].

3.1 Driver State and Performance Monitoring Module

The task of the Driver State and Performance Monitoring Module is to assess the driver's involvement in driving the train, to prevent him or her from getting out of the loop, but also his or her driving skills (driving performance, reaction time) to personalize the operation of the Digital Co-Driver. The Driver State and Performance Monitoring Module must therefore be able to evaluate 3 aspects: the ability to perform the driving task, performance and situation awareness. Various factors, which are difficult to quantify, influence the driver's ability to drive, including concentration, workload, motivation, and fatigue. The measurements intended to assess the driver's condition is divided into 3 categories. The first category concerns the evaluation of the driver's cognitive availability through eye-tracking[21], Thermal imaging[22], heart rate variability, EMG, EGG, and IMU[23]. Another possible indicator is the interaction between the driver and the train, as in automotive vehicles, where the interaction between the driver and the steering wheel can be monitored. The second category is about the evaluation of driving skills[24] can be envisaged with indicators such as driving energy efficiency, adherence to schedules, material wear and tear, passenger comfort via the study of acceleration, braking and jerk variations, and finally safety, for example by taking into account the speed of approach to signals and danger zones. The third category is related to indicator about monitoring the driver's situational awareness, we are considering the possibility of the system asking the driver questions to check driver's perception, comprehension, projection based on the information extracted by the advisor module either by using tactile screen or voice interaction. The use of a connected watch would be interesting, as it would also provide information on the driver's general state.

The Driver State and Performance Monitoring Module studies the effect of varying grades of assistance on the driver's involvement in the supervision or driving task. Depending on the driver's degree of involvement, the Digital Co-Driver can decide to give tasks back to the driver to reduce boredom or drowsiness. The driver needs system approval to automate those tasks again. If the driver is deemed out of the loop by the system or if the system detect a significant drop in driver's competence, it forces the driver to go back in GoA-2.1 and the system acts only as a supervisor of driving. To reduce the risk of nodding off during long periods of inactivity, it is envisaged to share traction control to the driver, or to take advantage of this time to train a novice driver. In fact, a number of studies have shown encouraging results in terms of the ability to regain control of an automated system when the operator is busy with a secondary task[25, 26].

3.2 Digital Adviser Module

In line with researchers' findings on the need to improve drivers' situational awareness[27], and the contribution of improved situation awareness to rail drivers' efficiency and anticipation [24, 28, 29], the Digital Co-Driver's advisor module filters network state information (delay, trackside state, trackside maintenance operation), information from ground control, and train information to provide the driver relevant data regarding driving tasks and planned timetable. These information are available to optimize operations during rail driving. To simplify the driver's task, he can also choose to have a display of the speed and traction recommended by the system for an optimized driving behaviour. The use of artificial intelligence-based solutions enables the system to maintain user profiles to personalize recommendations. The Digital Co-Driver's advisor module is able to communicate with the driver via a visual interface (touch screen or Head up Display) as well as a voice interface, in line with driver requests but also with the theory of limited resources to avoid saturating the optical channel, which is already heavily used in rail driving [29].

3.3 Digital Teacher Module

Studies have been carried out into the possibility of using ADAS to train drivers in the field of private vehicles. The learning capabilities of ADAS have already been validated for parking[30, 31], and a previous paper has succeeded in improving drivers' skills in economic driving[32], with possible interesting results once applied to rail driving. In order to avoid any potential loss of skills caused by the use of a highly automated system, the Digital Co-Driver's Teacher module finds and applies the best learning strategy for the system's driver, based on the results communicated to it by the Driver State and Performance Monitoring Module. System determines the best task distribution for each individual and thus personalize the collaboration by adapting it to the limits of each driver. Studies have already demonstrated the ability of AIs to learn and reproduce the driving skills of human drivers in the railway sector, using deep learning approaches[33]. Once properly trained, these AIs can then serve as a reference for the digital teacher module. It's interesting to note that an AI can learn even from novice drivers and help them to drive efficiently[34]. It takes into account the Human-Machine interface best suited to the current driver (haptic or visual), the most effective teaching method with this driver, but also the driver's willingness to cooperate and receptiveness to advice, in order to determine the optimum strategy for the driver.

4 Future implementation

The next step will be the implementation of the Driver State and Performance Monitoring Module to monitor the drivers and test new task allocation proposed by the authors in order to test the process in simulation to validate the hypothesis about the positive impact of varying the task allocation based on driver state to bring the driver active in the loop. In order to access the situation awareness without the relevant information filtered by the Digital Adviser Module we will have to pick relevant information by hand when building the simulation scenario. Different algorithms are going to be compared, using different paradigm, some off them are going to use AI techniques.
The second step will be to implement the Digital Teacher Module to adapt the DCD's actions to personal preference of driver and take into account the willingness of driver to cooperate with the automated agent. This step will check possibility to use an artificial intelligence to train drivers. Since we have no database regarding to train driving, we will have to find a way to use no data AI or find a way to quickly build data.
The third step will be to finish the implementation of the Digital Adviser Module. The aim of this module is to use AI to filter relevant information about driving and choosing the right time and adapted mean of communication to give the information to the driver. This data will be used by the Driver State and Performance Monitoring Module to assess situation awareness.

5 Conclusion

We propose an innovative approach, in which the artificial system takes into account not only the strengths and weaknesses of the human operator, but also its impact on the human operator and the willingness of the operator to cooperate with the DCD. The two major contributions of Digital Co-Driver is the ability to monitor the driver's level of availability and involvement in order to adapt the task distribution. The second one is to assess driving skills and propose a training program based on learning the driving practices of expert drivers. DCD was enabled with the introduction of intermediate Grade of Automation allowing a task sharing between the automated agent (the DCD) and the train driver: These new grades give the system time to learn from the human, to build data, enabling a gradual transition from a train with a driver to one without. Artificial intelligence human teams seems a promising solution for the development of new driver-centered rail assistance system. However, it will be crucial to avoid problems related not only to the involvement of the human operator, but also to the operator's ability to retain his/her driving skills and manage unforeseen events. To make the Digital Co-Driver even more in line with the standards set by Industry 5.0, a special effort will be made to improve driver well-being.

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Vers des outils d'aide à la conduite ferroviaire à base d'intelligence artificielle

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Vers des outils d'aide à la conduite ferroviaire à base d'intelligence artificielle

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Mots-clés : *Automatique, Intelligence Artificielle, Ferroviaire.*

1 Introduction

Les travaux présentés dans ce papier sont réalisés dans le cadre du Projet Academics4Rail, financé par Europe's Rail, qui est le nouveau partenariat européen dans le domaine ferroviaire créé dans le cadre du projet de recherche Horizon Europe. Le but d'Academics4Rail est de proposer des assistances aux conducteurs pour la conduite ferroviaire. Dans un premier temps, nous allons étudier les degrés d'automatisation pour proposer des niveaux supplémentaires qui correspondent à une assistance progressive à la conduite. Puis nous reprendrons une taxonomie des activités de conduite pour en extraire les tâches qui devront être automatisées et enfin nous étudierons les possibilités qu'offre l'intégration de l"Intelligence Artificielle dans le cadre de l'assistance à la conduite ferroviaire.

2 Niveaux d'automatisation

Les niveaux d'automatisation (GoA, Grades of Automation) définissent la répartition des actions entre le conducteur et les systèmes ferroviaires [1].

— **GoA-0 :**Conduite manuelle uniquement sans dispositif de protection automatique.
— **GoA-1 :**Conduite manuelle avec dispositif de protection automatique. Les systèmes automatisés concernent le respect des limitations de vitesse et des signaux de danger (ATP), La répétition des signaux en cabine (ERTMS), la VACMA.
— **GoA-2 :**Train semi-autonome : le conducteur reste l'autorité finale sur tous les systèmes, les outils d'aide peuvent agir mais uniquement sous la supervision du conducteur(ATO)
— **GoA-3 :**Train sans conducteur : il n'y a plus de conducteur à bord, le personnel naviguant est chargé de l'ouverture et la fermeture des portes ainsi que de la détection et la gestion des urgences.
— **GoA-4 :**Train autonome. Le train est entièrement automatisé, sous la supervision du Poste de Commande Centralisé.

Dans la Figure (1), les niveaux 2 et 3, les systèmes prennent en charge une partie de la gestion tactique et opérationnelle. Entre les niveaux 2 et 3 il y a un transfert de l'autorité, de l'homme à la machine. Ce transfert impacte la sécurité des usagers et la responsabilité légale en cas d'accident. D'autres échelles existent dans la littérature pour mesurer le niveau d'automatisation des systèmes, par exemple les travaux d'Endsley and Kaber[2], de Fereidunian[2]. Ces échelles proposent des niveaux intermédiaires entre le niveau 2 et 3 pour gérer le transfert d'autorité et la montée en compétence du système automatisé. Deux niveaux supplémentaires sont proposés. Ils permettent un passage naturel du niveau 2 au niveau 3. Les tâches stratégiques restent à la charge du conducteur. Afin que le système soit acceptable par les conducteurs[3], il faut que le conducteur conserve l'autorité finale. De plus le conducteur doit comprendre son

	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 – Proposition d'adaptation des degrés d'automatisation
https ://www.overleaf.com/project/65e07a4e73af2e58ae9ce0cc

système [3]. Au niveau 2.1, le système peut agir de manière autonome, pour les actions concernant son mouvement mais le conducteur reste actif et conserve l'autorité sur la supervision du mouvement du train dans son environnement. Le système vient enrichir la conscience de la situation du conducteur afin de l'aider à anticiper sa conduite. Le système peut alors acquérir les compétences dont il a besoin pour le niveau 2.2. Au niveau 2.2, un transfert d'autorité à lieu et le conducteur devient l'assistant du système pour les taches de conduite et de supervision de l'environnement que le système ne peut gérer seul. On laisse cependant au conducteur l'autorité finale. Le principal apport de ce nouveau découpage est qu'il permet de développer un système qui maintient le conducteur impliqué dans la tâche de conduite. Le conducteur peut reprendre en main à tout moment, ses compétences ne disparaissent pas et il est plus apte à réagir lorsque le système a besoin d'aide face à une situation inédite.
Dans la TAB. 1, les tâches opérationnelles et tactiques de la taxonomie des taches proposée dans la cadre du projet Carbodin [3] sont présentées.

	Opérationnelles	Tactiques
Critiques	**Régulation de vitesse**	**Fermeture / ouverture portes** **Surveillance de l'environnement**
Auxiliaires	Accessoires Alimentation	**Départ / arrêt en gare**
Supports	Eclairage Systèmes de confort	

TAB. 1 – niveaux de prise de décisions

Les tâches critiques de Régulation de vitesse et de surveillance de l'environnement sont à automatiser. Ces tâches ont déjà été automatisée séparément par des précédents travaux, notamment dans le cadre de l'économie d'énergie. Les tâches auxiliaires Accessoires et Alimentation est réclamée par les conducteurs [3]. Ils veulent un niveau d'automatisation comparables à leur voiture. Les tâches support Eclairage et Systèmes de confort font partie des tâches opérationnelles de la conduite et sont donc dans le scope de l'étude.

3 Apport de l'Intelligence Artificielle

Dans la littérature, il existe déjà des travaux menés sur l'intégration de l'intelligence artificielle dans des outils lié à la conduite ferroviaire. L'intelligence artificielle a aussi été utilisée pour la surveillance visuelle de la voie, Besinovic et Al [4] expliquent que l'apprentissage profond est la plus performante des techniques d'Intelligence Artificielle pour le traitement d'images. De nombreuses études ont été menées pour l'utilisation de l'IA dans la génération de profil de vitesse pour augmenter la rentabilité énergétique du train, par exemple : Approximate Dynamic Programming [5] Machine Learning et Deep Learning [4] [5], reinforcement learning, [5] SVM], Huang et al [6] ont proposé une approche orientée logique avec un arbre de décision flou pour apprendre l'expérience de conducteur humain. Les 2 arguments principaux pour l'utilisation des IA dans la conduite ferroviaire sont la capacité des Intelligences Artificielle à improviser lors des situations inconnues [4] qui vont arriver lors de la conduite ferroviaire ce qui répond au fonctionnement voulu du système au niveau 2.2. Les Intelligences Artificielles sont aussi capables d'apprendre et de mémoriser les solutions apportées par l'humain aux problèmes qu'elles n'auraient pas su résoudre [4] ce qui est le fonctionnement du système au niveau 2.1. De plus l'intelligence artificielle est capable de reconfigurer le modèle et de l'adapter à la situation.

4 Conclusion

L'intelligence artificielle semble une piste prometteuse pour développer de nouveaux systèmes d'aide à la conduite ferroviaire intégrant le conducteur. L'ajout de fonctions automatisées réclamées par les conducteurs augmenteraient potentiellement l'acceptabilité de ces aides. De plus, l'introduction des niveaux intermédiaires laisse un temps d'apprentissage au système ce qui permet une transition progressive d'un train avec conducteur vers un train sans conducteur.

5 Remerciements

Ce travail a bénéficié d'une aide au titre du programme-cadre de recherche et d'innovation de l'Union européenne Horizon Europe, projet Academics4Rail (HORIZON-ER-JU-2022-ExplR-04) No 101121842.
Ces travaux de recherche ont été financés par RITMEA, la Région Hauts-de-France, la Communauté Européenne, la Délégation Régionale à la Recherche et à la Technologie, le Ministère de l'Enseignement Supérieur, de la Recherche et de l'Innovation, et le Centre National de la Recherche Scientifique.

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Nouveaux Grades Opérationnels et Tactiques pour l'Automatisation ferroviaire

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Journée Régionale des Doctorants en Automatique

La Citadelle à Amiens, 24 Juin 2025

Nouveaux Grades Opérationnels et Tactiques pour l'Automatisation ferroviaire

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Introduction

Contexte

- Carbodin

H2020-S2RJU-OC-2019 Grant agreement n° 881814
WP10 : Innovative Driving Cabin

- creation of a survey on innovative driving interfaces
- creation of a simulator to test gesture and voice interfaces
- experimental protocol at LAMIH and in paris (21 drivers)

- Academics4Rail

HORIZON-ER-JU-2022 Grant agreement n° 101121842
Creation of a network of excellence of researchers and academics specialized in the railway field for EU-Rail, with the establishment of a network of doctoral students (academics working in collaboration with industry).

Problématique

How to keep the human driver involved ?
Detecting driver cognitive state.
Helping driver to be implied in driving.

How to keep the human driver able to back up the system ?
Operator need to have situational awareness.
Operator need to keep the skills and knowledge.

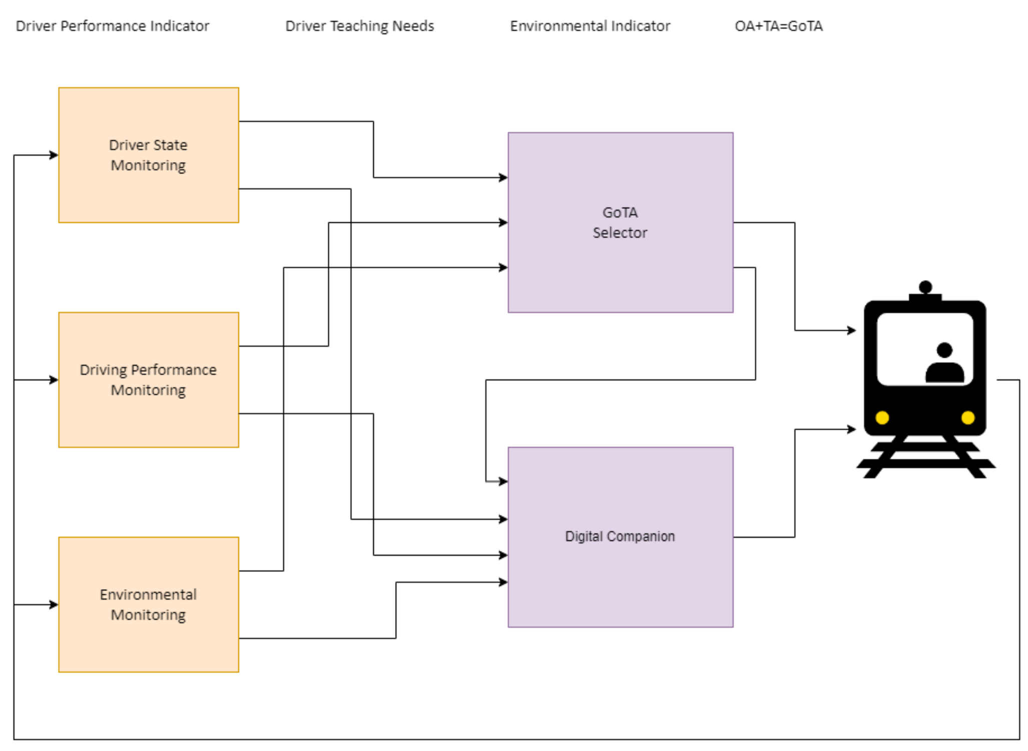
Objectif

Respond to the question risen by the first implementations of GoA3 trains about the transformation of the driver's role. He has gone from being the locomotive's active controller to the supervisor of a highly automated system.

Is there a driver on the train?

Architecture

We are therefore going to propose the creation of a digital assistant in the context of rail driving to mitigate the impact on the driver of GoA3 assistance.



3 Data acquisition modules

2 Processing modules

- Input
- Retrieval of data concerning the driver and the environment
  - DSM
  - DPM
  - EM

Architecture

- Output

Selection of assistance strategies and evaluation of outcomes

- GOTA Selector
- Driver Companion

GOTA

the GOTA unifies and standardizes all the assistance proposed in the train. This will facilitate the incorporation and management of Driver Advisory System (DAS) tools, which assist drivers in tactical planning, into the assessment of the requisite level of assistance

		Levels	Operational	Tactical
Operational and Tactical Automation	Grades of Automation	Driving tasks	Speed regulation Departure / stopping at station	Monitoring of driving environment Doors closure / opening
0.0	GoA-0		Driver	Driver
0.1			Driver	Driver \ System
0.2			Driver	System \ Driver
0.3			Driver	System
1.0	GoA-1	ATP	Driver \ System	Driver
1.1			Driver \ System	Driver \ System
1.2			Driver \ System	System \ Driver
1.3			Driver \ System	System
2.0	GoA-2	ATP+ATO	System \ Driver	Driver
2.1	*GoA-2.1*		System \ Driver	Driver \ System
2.2	*GoA-2.2*		System \ Driver	System \ Driver
2.3			System \ Driver	System
3.0			System	Driver
3.1			System	Driver \ System
3.2	GoA-3	Driverless	System	System \ Train attendant
3.3	GoA-4		System	System

That is why GOTA has been developed to provide a framework for a more nuanced approach to defining the levels of assistance required for each of the two groups of tactical or operational tasks, independently of each other.

DSI / DPI / EI

The framework utilizes three distinct input modules that generate indicators that are used to compute a driver assistance strategy.

DSM: Driver State Monitoring

- Based on the driver's physiological state

DPM: Driving Performance Monitoring

- Evaluates driver performance

EM: Environmental Monitoring

- Function of the environment in which the train is operating and train-driver interaction factors related to in-cab implementation

GOTA Selector

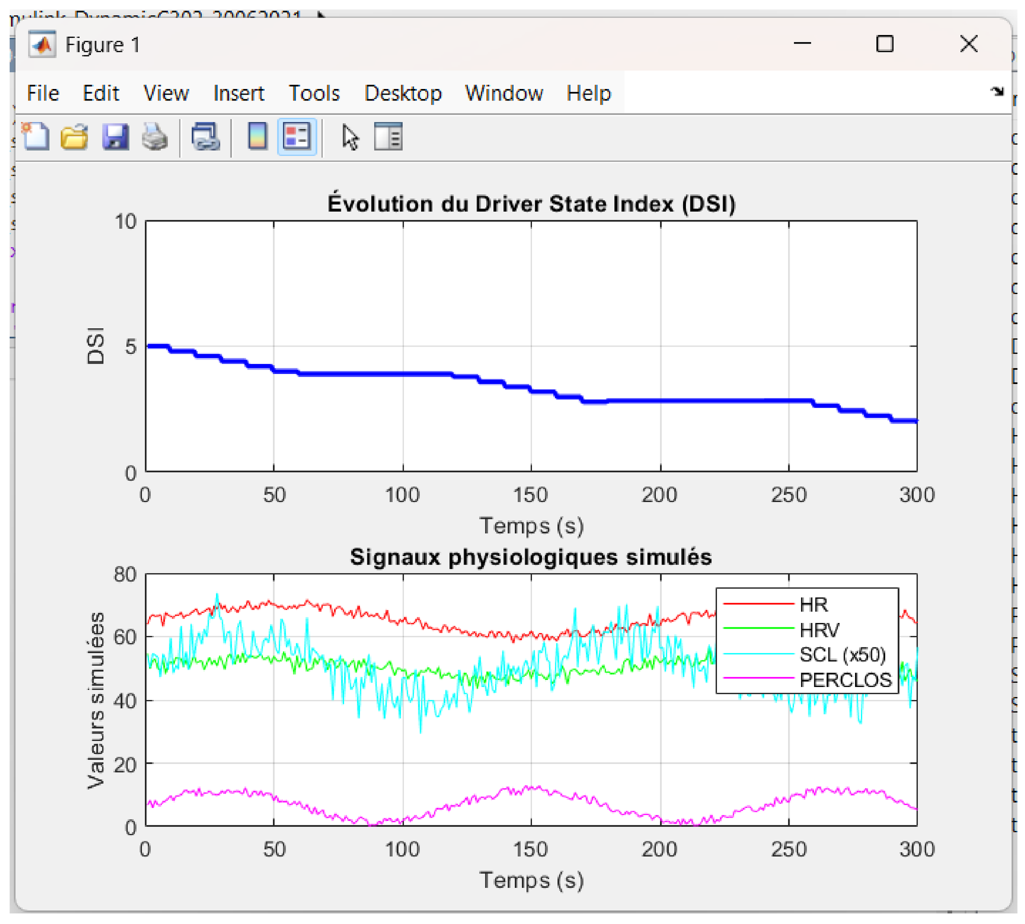
The GOTA Selector determine the best assistance strategy OA+TA (Operational and Tactical Automation) according to the circumstances, OA+TA entities constitute a combination of the GOTA. The refreshment rate of such the GOTA Selector will be determined during the experimental process and can vary for operational and tactical levels separately.

The selection of task allocation can be delegated to either a human or a machine. When the distribution process is delegated to the machine, the system is capable of implementing a variety of distribution strategies.

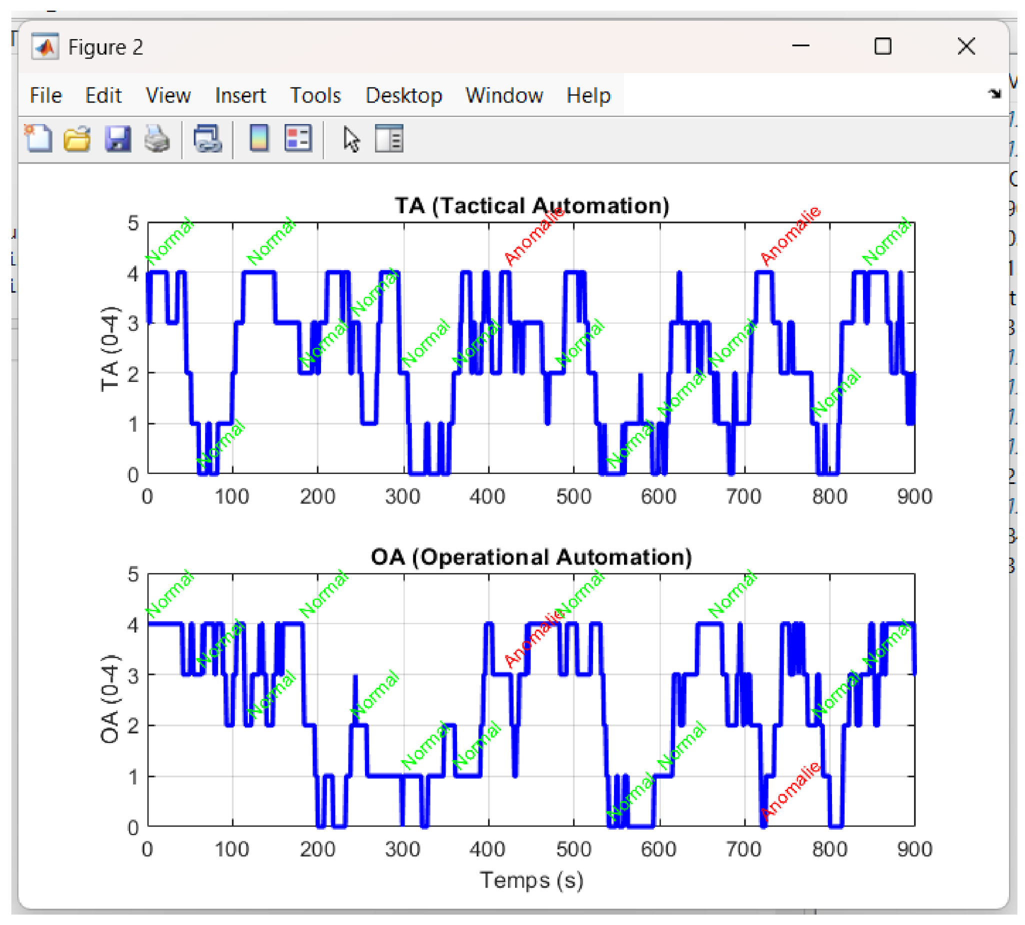
- Maximising Human Performance
- Avoiding Skill loss
- Reducing the driver's workload
- Assisting the most demanding part

Simulation

As demonstrated in the following example, the DSI has been calculated using simulated values.



As demonstrated in the following example, the GOTA has been calculated using simulated values.



Conclusions

Putting the human factor back at the heart of the automated system will ensure that the driving skills of expert drivers are retained and passed on to new drivers. And by keeping them active, drivers will be able to regain control of the train in the event of undesirable situations.

The addition of automated functions requested by drivers could potentially increase the acceptability of these aids. In addition, the introduction of intermediate levels gives the system time to learn, enabling a gradual transition from driver-controlled to driverless trains.

Disclaimer

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mis modélisation, information & systèmes

LTI

GRAISyHM Groupe d'Intérêt Scientifique de Recherche en Automatisation Intégrée et Systèmes Homme-Machine

Campus de la mer

Journée Régionale des Doctorants en Sciences de la Mer et Automatique

8 juillet 2024 au Centre Universitaire Le Musée à Boulogne-sur-Mer

Towards artificial intelligence-based rail driving assistance tools

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Introduction

In a context of preserving the earth's resources, public transport is a key sector. With networks that are difficult to upgrade facing an explosion in demand for passenger and freight transport, the only solution is to increase the frequency of service, further increasing the load on train drivers' shoulders.

We will therefore be proposing measures to enable them to cope with these changes in the best possible conditions, without endangering passengers.

Projet scientifique de la thèse

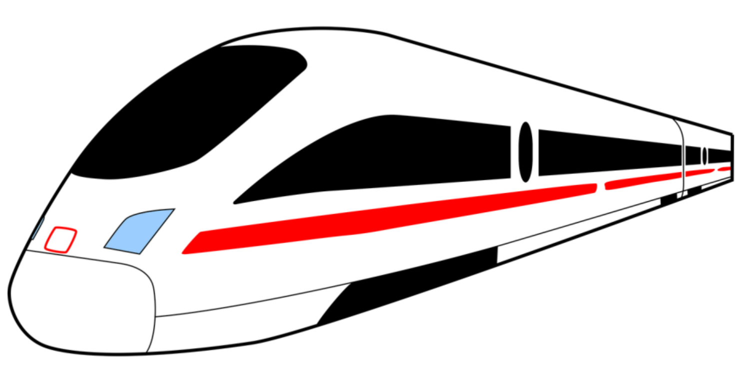
There are 5 different levels of automation in railway operation, known as Grades of Automation.

- 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.

	Levels	Operational	Operational	Tactic	Tactic	Strategic
Grades of Automation	Driving tasks	Speed regulation	Departure / stopping at station	Monitoring of driving environment	Doors closure / opening	Detection and management of emergencies
GoA-0		Driver	Driver	Driver	Driver	Driver
GoA-1	ATP	Driver \ System	Driver	Driver	Driver	Driver
GoA-2	ATP+ATO	System \ Driver	Driver \ System	Driver	Driver	Driver
GoA-3	Driverless	System	System	System	Train attendant	Train attendant
GoA-4		System	System	System	System	System \ Operational Control Center

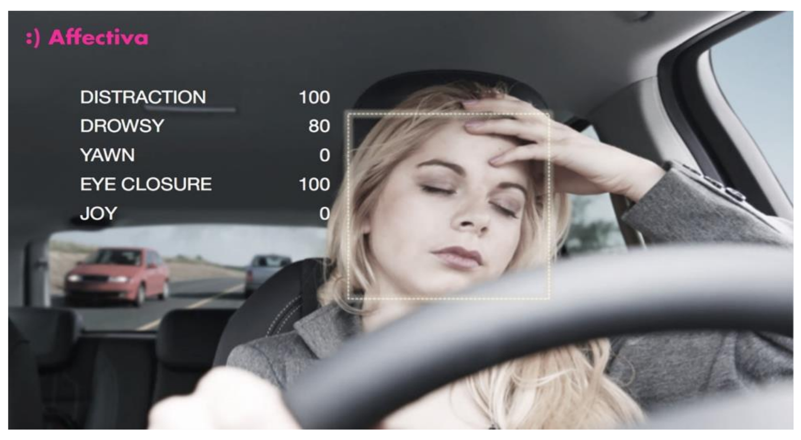
However, the first implementations raise questions about the transformation of the driver's role. He has gone from being the locomotive's active controller to the supervisor of a highly automated system.

Is there a driver on the train?



In the literature, there is a great deal of research on the difficulty for operators to remain active in a supervisory task.
Among the major problems that have a direct impact on train safety are the following

I. Driver Un-involvement (Brandenburger et al., 2021)
II. Situation Un-Awareness (Rad et al., 2021)
III. Skill loss (Nordhoff et al. 2023)
IV. Underload (Brandenburger & Naumann, 2019)
V. Trust, Complacency, and Over-Reliance (Nordhoff et al., 2023)
VI. Drowsiness (Naujoks et al., 2018)



Studies are already underway to enable humans and intelligent systems to cooperate effectively, taking into account the mechanisms of human cognition.

- Hybrid Human-Artificial Intelligence (Ning et al., 2022)
  - Situation awareness (Sanneman & Shah, 2020)
  - Transparency (Endsley, 2023)
  - Explainability (Endsley, 2023)
- Co-evolution (Lu et al., 2022)
- HMI impact (Verstappen et al., 2017) ....

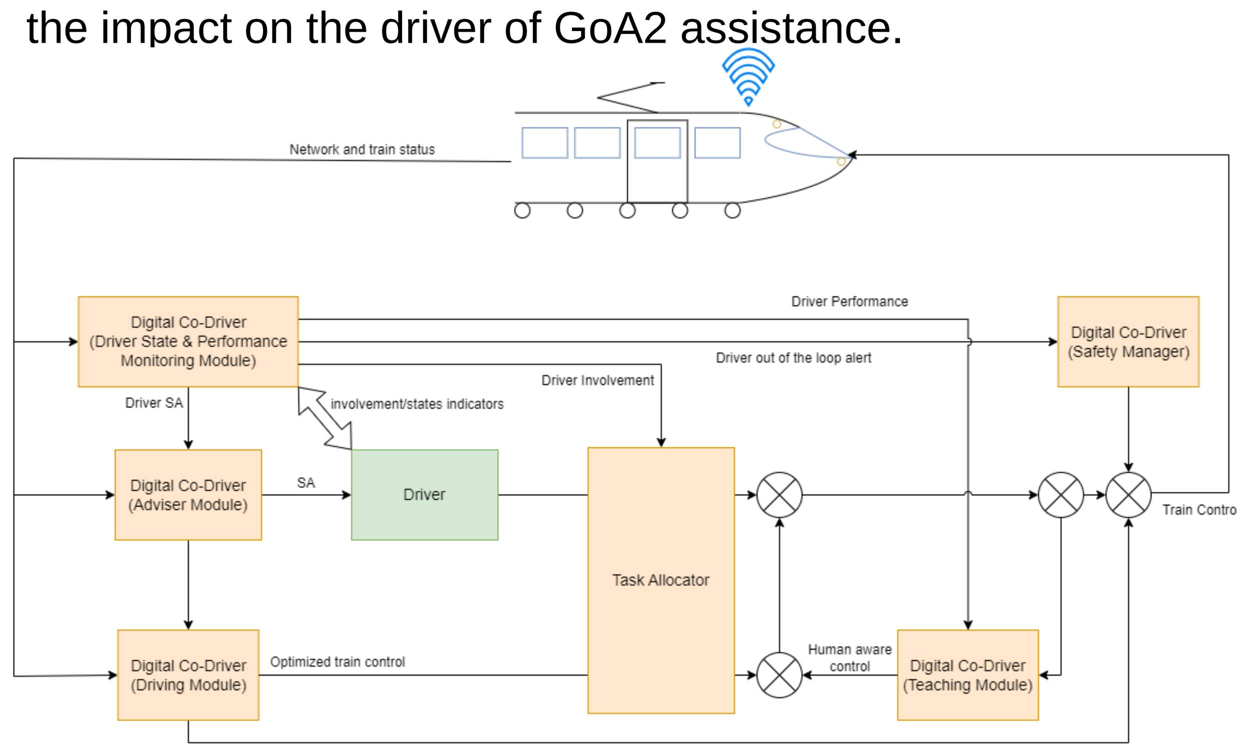
Propositions de la thèse

We are going to propose a more fluid design of GoAs by adding intermediate levels, but also by allowing the system to evolve between GoAs according to the situation of the network and the driver.

- 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 situational awareness, helping him to anticipate his driving.
- At level 2.2, 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. It makes possible to develop a system that keeps the driver involved in the driving task. The driver can retake control at any time, he is better disposed to react when the system needs help in a new situation.

	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

We are therefore going to propose the creation of a digital assistant in the context of rail driving to mitigate the impact on the driver of GoA2 assistance.



It's an anthropocentric system, made up of 4 parts, each responding to a problem generated by the addition of driving aids

- **Driver monitoring System**
Keep driver involved
- **Digital Adviser**
Enhance driver SA
- **Digital Teacher**
Improve driver's skill
- **Safety Manager**
IA SIL integration

Driver monitoring System

- Involvement and Workload monitoring
- Performance monitoring
- Situation Awareness monitoring

Digital Adviser

- Filters out relevant information that will have an impact on the driving process
- Personalize information according to the user
- Creating and updating driver profiles

Digital Teacher

- Creating and updating driver profiles
- Assesses different teaching methods
- Adapting training to drivers' interactions

Safety Manager

- Ensures that the AI's actions comply with the rules laid down by SNCF
- Secures the train if the driver is deemed unfit to drive

Conclusion

Artificial intelligence seems to be a promising approach to the development of new driver-centric rail assistance systems.
Putting the human factor back at the heart of the automated system will ensure that the driving skills of expert drivers are retained and passed on to new drivers. And by keeping them active, drivers will be able to regain control of the train in the event of undesirable situations.
The addition of automated functions requested by drivers could potentially increase the acceptability of these aids. In addition, the introduction of intermediate levels gives the system time to learn, enabling a gradual transition from driver-controlled to driverless trains.

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