COSYS Department
ESTAS laboratory newsletter

May 2023

Editorial by the director

Since the 1st of January, 2023, I have taken on the responsibility of leading the ESTAS laboratory. This issue of the ESTAS newsletter is therefore the first of this new five-year term.

Since its creation, the ESTAS laboratory has developed significant know-how on a wide spectrum of topics pertaining to safety analysis and operation of guided transportation systems. The obtained scientific results, the involvement of ESTAS in numerous national and international projects, and the services of expertise and technical assistance that it has provided on various guided transport systems worldwide, have earned the lab a leading position on its research topics, as well as national and international notoriety. On the scientific level, the laboratory's new scientific project capitalizes on previous works, while emphasizing the new generation of control-command and signaling systems that involve new concepts and paradigms in terms of train movement management (mobile block, virtual fixed block, virtual coupling), and in terms of control-supervision (autonomous driving, artificial intelligence). These developments lead to major changes in railway operation, while impacting various command-control functions (localization, integrity management, environmental monitoring, etc.). ESTAS aims to support these breakthroughs while operating synergies towards other modes of transport, in particular road transport in relation to autonomous driving and safety analysis of its related artificial intelligence based funcions.

On the other hand, this new mandate is characterized by the retirement of several members of the laboratory. Therefore, a major challenge facing the laboratory is to recruit new personnel in order to fill these departures and continue to develop its scientific and technical capital around guided transportation.

In this issue, you will find a presentation of the concept of "hybrid" public transport, where both fixed stops and stops-on-request are served in some given operation area. This letter also sheds light on the contribution of ESTAS to the implementation of an application guide relating to the mission of the qualified organization approved for safety evaluation and safety audit of Automated Road Transport Systems (ARTS). In addition, the lab is taking part in two new projects: the first

is the European H2020 MOTIONAL project within the framework of the Europe's Rail program, in which ESTAS will develop new rail traffic management algorithms in association with SNCF, inter alia. The second is the national FERROMOBILE project, which ambitions to adapt technologies from the automotive sector to the rail domain in order to develop an innovative on-demand, multimodal and shared mobility solution while targeting particularly narrow service lines. In addition, the results of a thesis which was defended recently in the laboratory are outlined. This thesis work focused on the use of formal approaches for the evaluation of the safety of the GNSS-based railway location function. Finally, still in the News section, the scientific events in which the laboratory staff took part, as well as a list of new publications, are presented.

Wishing you a very good reading.

Mohamed Ghazel, Director of ESTAS

On-demand hybrid public transportation: the case of Flex Route Transit (FRT)

In order to face increasing levels of demand in specific area and in specific moments, several local operators have explored a type of "hybrid" public transportation (e.g. in Los Angeles, Harbin,...). This Flex Route Transit (FRT) system is based on a classic public transportation bus line with a few fixed stops based on a predetermined timetable. The service shuttle can however leave the route to pick-up or drop-off customers who booked an on-demand trip at additional stops, as long as they are within a specific service area and do not generate a late departure at the fixed stops. Reza Shahin's PhD inside ESTAS studies the impact of the choice of system parameters (timetable, fleet capacity, size of the service area,...) on the potential level of service of FRT, using sensitivity analysis and tactical optimisation models (stochastic optimisation).
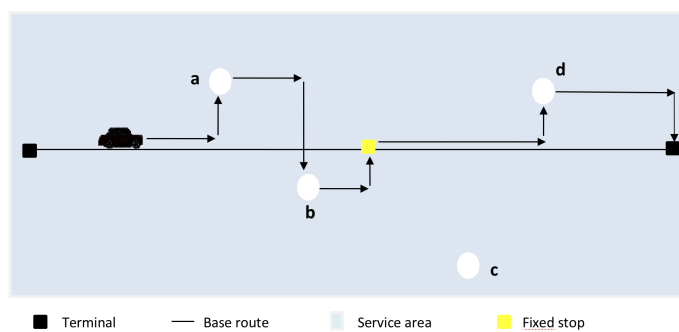
Example of an FRT line, with two terminals, an intermediate fixed stop (in yellow) and the service area in grey, along with a tentative route for the shuttle allowing to serve the demands a, b and d while also serving the fixed stops.

Contact : Pierre Hosteins

News and events

ESTAS contribution to the application guide concerning the mission of the approved qualified body for the safety assessment and the safety

audit in operation of ARTS **

ESTAS contributed, on the basis of its expertise in the field of guided transport safety, to the drafting of the application guide relating to the mission of the approved qualified body (AQB) for the safety assessment and safety audit of the operation of ARTS by participating in the meetings of the specific national working group set up by the STRMTG*** to specify these missions. This guide follows on from the "GAME Application Guide for Automated Road Transport Systems" published in December 2021 and the "Technical Guide to GAME Demonstration for ARTS" published in August 2022.
This first official version of the guide published in October 2022 explains :

- the expected mission of the Approved Qualified Body (AQB) for the safety assessment of new Automated Road Transport Systems (ARTS) or substantial modifications of existing systems,
- the expected mission of the AQB for tests in driving delegation,
- the expected mission of the AQB for the annual safety audit in operation of ARTS,
- the expected mission of the AQB for the safety diagnosis of ARTS,
- the task expected of the AQB for the opinion on the accident analysis report.

This guide is intended for all professional actors in the automated road transport sector.

*GAME: Globally equal or less risky: the level of safety of a new system compared to that of a system already in operation.
** ARTS: Automated Road Transport Systems.
*** STRMTG: Service Technique des Remontées Mécaniques et des Transports Guidés, a department of the French Ministry of Transport.

Read more

Application guide concerning the mission of the approved qualified body for the safety assessment and the safety audit in operation of ARTS

Contact : François Baranowski

New projects

MOTIONAL H2020 project
MOTIONAL is a project funded under the Europe's Rail Joint Undertaking*, Flagship Area 1. It is coordinated by Hacon Ingenieurgesellschaft mbH and it includes 29 partners. The traffic management team of the ESTAS laboratory participates in this project as an affiliated entity of SNCF. Specifically, it intervenes in WP17 (Development - Automated decisions and decision support for traffic management optimisation) and 18 (Demonstration - Automated decisions

and decision support for traffic management optimisation). The work will focus on the design of traffic management algorithms for large networks, considering the latest envisaged technological evolutions (moving block, virtual coupling, ...). Moreover, the algorithm performance will be assessed in simulation, to mimic a possible practical deployment. The project started on December 1st, 2022, and will last 46 months. The kick-off was held in Hanover (Germany) on January 25th, 2023 with the participation of representatives of all project partners.

* European partnership for rail research and innovation under the Horizon Europe programme (2020-2027). It is the successor to the Shift2Rail Joint Undertaking.

Contact : Paola Pellegrini

FERROMOBILE: an innovative on-demand, multimodal and shared mobility solution

The FERROMOBILE project aims to develop and test an innovative on-demand, multimodal and shared mobility solution to meet the challenges posed by public passenger transport. The envisaged solution will be particularly suitable for fine feeder lines, by bringing the rail sector closer to the technologies of the automotive domain.

The adaptation of passenger transport automotive vehicles to mixed rail-road use, coupled with an automated rail transport system with a centralized Operating Assistance System, makes it possible to change the paradigm and offer truly innovative services (here).

The involvement of the Université Gustave Eiffel is supported by a fairly substantial research budget (4 PhD theses and 5 post-doctoral students), and is relevant to the following key topics:

1. Traffic management
2. Level crossings
3. Operational safety
4. Connectivity
5. Wheel/rail contact
6. Localization
7. Assessment of environmental performances

The ESTAS laboratory contributes to the first three themes. For the traffic management topic, ESTAS is involved in the mixed cyclic/on-demand regulation function. In response to traveler demands, the laboratory will develop a vehicle allocation optimization algorithm to reduce waiting times at hubs. In addition, ESTAS, in collaboration with some Lyon teams from Université Gustave Eiffel, will investigate the level crossing operation and safety, while considering level crossings as a road intersections on the outskirts of built-up areas. Finally, the autonomous control of the new vehicle, called "Ferromobile", will be approached by ESTAS teams from a safety point of view by bringing into play formal methods as recommended by railway standards. The objective is to help certify the safety of driverless operations.

Partners : AKKODIS, ALSTOM, SYSTRA, Entropy, Université Gustave Eiffel, Région Occitanie.

Contact : Simon Collart-Dutilleul

Scientific events

WAISE   Workshop   in   the   SAFECOMP   2022   conference

(International Conference on Computer Safety, Reliability and Security) in Munich, Germany - 6 to 9 September 2022

- [Interval weight-based abstraction for neural network verification](#), **F. Boudardara**, A. Boussif, **P.-J. Meyer**, **M. Ghazel**.

Lambda-Mu congress in Paris-Saclay, France - 11 to 13 October 2022

- [Argumentaire de sécurité graphique pour l'assurance de sécurité des trains autonomes](#), **Chelouati M**., Boussif A., **Beugin J.**, **El-Koursi E.-M.**.

PERFORMINGRAIL* project workshop entitled "Moving Block rail signalling... the long and winding road" - October 20, 2022
PERFORMINGRAIL is a European project supported by Shift2Rail that started in 2020. It aims to implement a system approach to tackle the challenges for enabling the moving-block and virtual coupling concepts in terms of safe operational principles and specifications. The online workshop was held on October 20, 2022..

Partners : Université Gustave Eiffel, University of Birmingham, CINI, Mälardalen University, TU Delft, CERTIFER, Eulynx, Rokubun.

* PERformance-based Formal modelling and Optimal tRaffic Management for movING-block RAILway signalling

[Read more](#)

9th TRA 2022 conference in Lisbon, Portugal - 14 to 17 November 2022
Four ESTAS papers at the TRA 2022 conference :

- Methodology Framework for Modelling ETCS-L3 Moving Block System, **Saddem-Yagoubi R.**, **Beugin J.**, **Ghazel M.**
- A Safety Assurance Methodology for Autonomous Trains**,** Tonk A.**, Chelouati M.**, Boussif A., **Beugin J.**, **El-Koursi E.-M.**
- Coordinated train rerouting and rescheduling in large infrastructures**, Yi X., Marlière G., Pellegrini P., Rodriguez J.,** Pesenti R.
- New Onboard Train Integrity and Train Length Determination: What are the Safety Requirements?, Sassi I., **El-Koursi E.-M.**, Iovino S.D., Ricevuto N.

IEEE Conference on Decision and Control (CDC) 2022 in Cancun, Mexico - 6 to 9 December 2022

- Reachability analysis of neural networks using mixed monotonicity, **Meyer P.-J.**

Open Science Workshop (2nd edition) - University Gustave Eiffel/ONCF/EMI, Rabat (Morocco) - 12 &13 December 2022
The 2nd open science workshop dedicated to railway safety and human factors held successfully on 12 & 13 December, 2022, in rabat (morocco). The Theme for the workshop is to bring together innovative academics and industrial experts to a common forum and to share the technology advancements in transport autonomy sectors and their impact

on safety. Researchers and practitioners (EPSF, SNCF, ERA, ONCF, University Gustave Eiffel, EMI, NARSA, Royal Air Maroc, Direction Générale des ports, and CNAM) shared their researches, developments and expertise in the autonomy field.

24th ROADEF 2023 congress in Rennes, France - 20 to 23 February 2023
Four ESTAS papers at the ROADEFF 2023 congress :

- Self-organization for train rescheduling and re-routing: a proof of concept, D'Amato L., **Naldini F.** , Tibaldo V., Trianni V. , **Pellegrini P.**
- Robustness analysis of railway rerouting and rescheduling to driving behaviour noise**, David B. , Pascariu B., Pellegrini P., Marlière G.**
- Real-time train rescheduling for connecting trains**, Sharma B., Pellegrini P., Rodriguez J.,** Chaudhary N.
- Rerouting and rescheduling the coordinated train management problem via an iterative algorithm**, Yi X., Marlière G., Pellegrini P., Rodriguez J.,** Pesenti R.

RailBelgrade 2023 : 10th International Conference on Railway Operations Modelling and Analysis (ICROMA) à Belgrade, Serbie - 25 au 28 Avril 2023
Six ESTAS papers :

- Railway Traffic Optimization: Robustness to Driving Behaviour Noise, **Pascariu B.**, **David B.**, **Pellegrini P.**, **Marlière G.**.
- Railway Rescheduling Considering Rerouting of Connecting Trains after Perturbations**, Sharma B., Pellegrini P., Rodriguez J.,** Chaudhary N.**.**
- Designing self-organizing railway traffic management**,** D'Amato L., **Naldini F.**, Tibaldo V., Trianni V., **Pellegrini P.**.
- An Approximate Conflict Detection and Resolution Model for Moving-Block Signalling by Enhancing RECIFE-MILP, **Versluis N.D., Pellegrini P.**, Quaglietta E., Goverde R.M.P., **Rodriguez J.**
- Coordinated train rerouting and rescheduling in large infrastructures**, Yi X., Marlière G., Pellegrini P., Rodriguez J.,** Pesenti R.
- A multi-objective framework for strategic railway timetabling: integration of ant colony optimization and mixed integer linear programming, Coviello N., Medeossi G., Nygreen T., **Pellegrini P., Rodriguez J.**

One ESTAS poster :

- Assessing self-organization algorithms for railway traffic: the selection of three case studies for the SORTEDMOBILITY research project, Cerreto F., **Pellegrini P.,** Chevrier R., Tavano F.

[Read more](#)

Defended PhD

Ouail Himrane defended his PhD entitled **"Contribution to Safety and Operational Performance Evaluation of GNSS-based Railway Localization Systems Using a Formal Model-based Approach"** on

December 16, 2022.

The implementation of more flexible railway operating principles, such as moving blocks, allow for increasing line capacity while reducing maintenance and operating costs. The establishment of these principles relies on autonomous train localisation solutions, which today are mainly based on GNSS technology (Global Navigation Satellite System). However, the introduction of such technological innovations in train control-command leads to the emergence of new risks. These risks need to be investigated meticulously, and some confidence level has to be assigned to GNSS-based localisation solutions in order to be used safely. Consequently, one of the main challenges is to provide safety proofs allowing the certification of these new systems by using safety analysis techniques able to apprehend the associated complex interactions.

These PhD works are part of this context by bringing formal approaches into play in order to evaluate performance and safety properties related to the use of GNSS-based virtual balises for train localisation. Specifically, the adopted model-oriented approach consists in translating the relevant behaviour of the localisation system through configurable timed and probabilistic automata. Concretely, these notations allow the time and random aspects of the localisation function behaviour to be taken into account, in order to reflect the uncertainties related to GNSS in a reliable way. The elaborated models being parameterizable, various operational scenarios, considering a wide range of configurations can be investigated. This possibility of analysis is particularly suitable considering the impact of environmental conditions on GNSS performance. Analysis results can be obtained on the basis of the developed models using Statistical Model Checking algorithms. The UPPAAL-SMC modelling and verification tool is employed. Two case studies are used to illustrate the application of the presented approach, and various numerical analysis results are provided. As the present contribution implements a model-driven approach to perform safety analysis in railways, it is fully in line with the increasing willingness to reduce recourse to on-site tests in the sector. Such tests are indeed costly and time-consuming, thus jeopardizing the introduction of technical innovations in railways.

The results of these PhD works have been valued in the PERFORMINGRAIL European project [Himrane et al. 2023].

Contact : Julie Beugin

New PhDs

Start of the Rim Brahim's PhD in April 2023 for 3 years on : Safety of an autonomous rail vehicle running on tyres at level crossings in the framework of the FERROMOBILE project supported by ADEME.
Contact : Simon Collart-Dutilleul

Start of the Amine Hamidi's PhD in January 2023 for 3 years around the formalisation of the software component of an innovative autonomous rail transport in the framework of the FERROMOBILE project supported by ADEME.
Contact : Simon Collart-Dutilleul

A new research director joins the ESTAS team

Paola Pellegrini joined the ESTAS laboratory on January 1st, 2023. She integrated the "Traffic management" team with which she has been collaborating for many years. Her scientific activities focus on the design of algorithms for managing railway infrastructure capacity. To do so, she

exploits the cross fertilization with this transport mode and the air and maritime ones.

Publication of papers

Chouchane A., **Ghazel M.**, Boussif A., [K-diagnosability analysis of bounded and unbounded Petri nets using linear optimization](), Automatica, Volume 147, 2023, 110689, ISSN 0005-1098, January 2023.

Peres F., Ghazel M., [A proven translation from a UML state machine subset to timed automata](), ACM Transactions on Embedded Computing Systems, January 2023.

Chelouati M., Boussif A., **Beugin J.**, **El-Koursi E.M.**, [A Graphical safety assurance case using Goal Structuring Notation (GSN) - challenges, opportunities and a framework for autonomous trains](). Journal of Reliability Engineering & System Safety (RESS), vol. 230, February 2023.

Liang C., Ghazel M., [Accident Prediction Modeling Approaches for European Railway Level Crossing Safety](), In book: New Research on Railway Engineering and Transport, Intechopen, DOI: 10.5772/intechopen.109865, March 2023.

Marlière G., **Sobieraj Richard S.**, **Pellegrini P.**, **Rodriguez J.**, [A conditional time-intervals formulation of the real-time Railway Traffic Management Problem](). Control Engineering Practice, Volume 133, April 2023.

Himrane O., **Beugin J.** and **Ghazel M.**, "[Implementation of a Model-Oriented Approach for Supporting Safe Integration of GNSS-Based Virtual Balises in ERTMS/ETCS Level 3]()" in IEEE Open Journal of Intelligent Transportation Systems, doi: 10.1109/OJITS.2023.3267142, April 2023.