Ph.D. COURSE IN INDUSTRIAL ENGINEERING – XXXIV CYCLE

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Scientific Committee:

Abstract of the thesis

Mobility in smart cities is also becoming smart, promoting on the one hand transport modes based on zero-emission electrical technologies and on the other providing vehicles with technological solutions that support the drivers in driving operations.

The winning key for mobility in the cities of the near future, therefore, are electrified transport solutions with assisted driving: the tram is the ideal candidate for this revolution of green and safe mobility.

Only in 2019, road accidents in the European Union summed up to 22.660 fatalities and 120.000 people seriously injured. However, the trend of accidents is decreasing every year and looking to the past, the decrease coincides with the market penetration of Advanced Driver Assistance Systems (ADAS).

Nowadays, almost all manufacturers offer cars with level 3 of driving automation (SAE 3 levels) and many prototypes of self-driving vehicles are developing and circulating on our roads. From a medium-term perspective, all vehicles running in the smart city will be equipped with autonomous driving technology or advanced driving aids, including public transport vehicles, such as buses. It is clear, therefore, that even for trams, the time is ripe to accommodate driving support systems. Just the tram is

experiencing a new spring today, due to its green nature that makes it a candidate for sustainable city mobility, and it will be the next candidate to host ADAS technologies. Trams are the combination of two worlds: railways and the road environment. Infect, unlike the other rail transport systems, use the same road infrastructure as cars, motorbikes, bikes, and pedestrians and will soon find themselves interacting with vehicles with increasingly higher autonomous driving levels. It is clear, therefore, that even for trams, the time is ripe to accommodate driving support systems.

From a technological point of view, tram manufacturers are moving towards the use and integration of automotive solutions, already available with a high level of maturity and reliability, based on Sensor Fusion and Perception Platforms.

However, due to the very different stopping times, a careful analysis of the tram braking dynamics to identify the most suitable technological solution is necessary.

The purpose of my thesis is to provide a contribution to the implementation of a driving assistance system designed for the tram, here called T-ADAS, by developing a model for Estimation of the Distance to Collision (DCE) fitted to the tram.

In the thesis, the key elements of technological porting and the choice of functionalities for a T-ADAS system according to the Degrees of Automation (GoA) are initially investigated and defined. The degrees/levels of automation in automotive and railway systems are presented and compared to each other. Then, according to the implication level of a remote sensing system in each tram driving task, new GoAs for tram are proposed. These systems are designed to help the tram driver cope with potential hazards by having defensive driving. Therefore, the proposed GoAs correlated to ADAS will be useful to understand how this automation acts the action of the tram driver, and the safety of the entire transport system.

The problem of braking for the tram is then analyzed to define quantitative requirements for the design and validation of the Forward Collision Earning (FCW) and Autonomous Emergency Braking (AEB) systems that takes into account the very different dynamics from the car. Those technologies are today widespread in the automotive sector: in fact, vehicle collision warning systems have been studied by

many researchers, and many approaches related to technologies and problem formulation has been developed and a lot of commercial solutions today are available. Among the ADAS, FCW-AEB systems represents the one with the highest percentage of crash avoidance effectiveness: FCW alone, low-speed AEB, and FCW with AEB reduced rear-end striking crash involvement rates by 27%, 43%, and 50%, respectively. For this purpose, the proposed DCE model, which uses tram and tramway data (mass, power, grip, slope, radius of curvature) and real-time data (speed, weather conditions, and GPS) will allow the calculation of the safety braking distance.

The main difference between the model proposed and those of the literature and/or of the commercial ones, is mainly related to the vehicle dynamic. Therefore, in the proposed approach, instead of considering only the deceleration and speed data to calculate the stopping distance, we consider many other important factors that tune this calculation to the real one.

The robustness of the model was verified by comparing the values obtained with the theoretical and real values recorded on the tram, the latter obtained from a test campaign carried out on Hitachi vehicles in collaboration with an Italian transport company (ANM) that operates trams in the city of Neaples.

The T-ADAS system is integrated into the vehicle logic by considering the driver's actions through the manipulator. When the designated braking action is not performed correctly, the system will adapt the braking curve to model one.

In the final part, the implementation of the T-ADAS in the on-board network of the tram will be provided and the evaluation of the data traffic is performed.

Infect, the newest railway network infrastructures based on Ethernet bus technologies can facilitate the integration of the T-ADAS systems with the Train Control Management System (TCMS), providing larger bandwidth and more flexible networks making this technology immediately transferable to railway systems such as the tram.

Throughout the entire work of the thesis, the real braking data of the case study and implementation approach were provided by the ANM and Hitachi Rail S.p.A which the author is grateful for the contribution offered.

Research activity outside UniSA:

Date	Total days	Host Institution	Supervisor	Activities
08/03/2021 to 31/10/2021	237	Hitachi Rail s.p.a	Ing. Luigi Fratelli Prof. Vincenzo Galdi	T-ADAS analysis and implementation study.
20/02/2020	1	Hitachi Rail s.p.a	Ing. Luigi Fratelli Prof. Vincenzo Galdi	ADAS analysis for tram
08/04/2020	1	Hitachi Rail s.p.a	Ing. Luigi Fratelli Prof. Vincenzo Galdi	ADAS analysis for tram
14/04/2020	1	Hitachi Rail s.p.a	Ing. Luigi Fratelli Prof. Vincenzo Galdi	ADAS analysis for tram
27/05/2020	1	ANM	Prof. Vincenzo Galdi Ing. Pierpaolo Martino	Study of sensors positioning
10/06/2020	1	ANM	Prof. Vincenzo Galdi Ing. Pierpaolo Martino	Study of sensors positioning
19/06/2020	1	ANM	Prof. Vincenzo Galdi Ing. Pierpaolo Martino	Braking tests
01/07/2020	1	ANM	Prof. Vincenzo Galdi Ing. Pierpaolo Martino	Braking tests
02/07/2020	1	Hitachi Rail s.p.a	Ing. Luigi Fratelli Prof. Vincenzo Galdi	ADAS analysis for tram
29/05/2019	1	Hitachi Rail s.p.a	Ing. Luigi Fratelli Prof. Vincenzo Galdi	Electric Tram System
13/09/2019	1	Hitachi Rail s.p.a	Ing. Luigi Fratelli Prof. Vincenzo Galdi	DAS in rail applications

Conferences:

Conference	Location	Date	Title of the contribution	Authors
Oral contribution				
WCRR-22	Birmingham	Under review	Communication Infrastructure Requirements to include ADAS Technologies in New Generation	Catello Di Palma. Vincenzo Galdi. Vito Calderaro.
Calgary2022	Calgary	Under review	Weigh-In-Motion based on FBG sensors for Smart Road Applications	Catello Di Palma. Vincenzo Galdi. Vito Calderaro. Piero De Fazio Luigi Carrarini Gianvittorio Rizzano
Poster contribution				
EEEIC2020	Madrid	10/06/2020	Driver Assistance System for Trams: Smart Tram in Smart Cities	Catello Di Palma. Vincenzo Galdi. Vito Calderaro.

Participation (no presentation)				

Courses outside UniSA and workshops:

Course/Workshop	Location	Date	Organizing Institution	Hours of training activities
Safety course	Hitachi Rail s.p.a	30/03/2021	Hitachi Rail s.p.a	16
DOORS course	Hitachi Rail s.p.a	05/04/2021	Altran	36
GPLM course	Hitachi Rail s.p.a	10/05/2021	Hitachi Rail s.p.a	16
Wind electricity	San Marco dei Cavoti	10/05/2019	IVPC	8
Electric turbogas generators	Napoli	17/05/2019	Tirreno Power s.p.a.	8
Development of rail transport	Napoli	21/05/2019	Museo Nazionale Ferroviario di Pietrarsa	6
Electricity dispatching	Pozzuoli	04/06/2019	Terna Rete Italiana s.p.a.	8
Microcontrollers for automotive applications	Arzano	27/05/2019	STMicroelectronics	8

Teaching assistance:

Course	Course of study	Date	Type of activity	Total hours
AIE	Electronics	22/04/2020	Tutoring: Protection and grounding	2
AIE	Electronics	29/04/2020	Tutoring: Protection switches	2
AIE	Electronics	06/05/2020	Tutoring: Electrical system design	2
AIE	Electronics	13/05/2020	Tutoring: Lighting technology	2
AIE	Electronics	20/05/2020	Tutoring: Fundamental principles of electrical circuits	2
AIE	Electronics	25/05/2020	Tutoring: Electrical system design	1
AIE	Electronics	28/05/2020	Tutoring: Electrical system design	1
AIE	Electronics	03/06/2020	Tutoring: Analysis of electrical loads	1

AIE	Electronics	11/06/2020	Tutoring: Analysis of electrical loads	1
MIE	Electronics	23/04/2020	Tutoring: AC/DC converters	2
MIE	Electronics	30/04/2020	Tutoring: DC/DC converters	2
MIE	Electronics	14/05/2020	Tutoring: circuit design	2
MIE	Electronics	21/05/2020	Tutoring: circuit design	2
MIE	Electronics	04/06/2020	Tutoring: circuit simulation	2
AIE	Electronics	15/04/2019	Tutoring: Introduction to electrical machines	2
AIE	Electronics	06/05/2019	Tutoring: Rotor and stator coil for DC motors	2
AIE	Electronics	13/05/2019	Tutoring: Constructive provisions for DC machines	2
AIE	Electronics	20/05/2019	Tutoring: Collector motor - general considerations	2
AIE	Electronics	23/05/2019	Tutoring: Fundamental principles of electrical circuits	2

Attended courses (specify if internal or external and if I, II or III level):

Course	**Type of activity**	**Hours of training activities**	**Exam (yes or no)**	**Exam mark (if not available, please indicate pass/no pass)**
Third year				
BatterFly: "Progettazione e misura di un sistema di filtraggio per un convertitore AC/DC"	Webinar for upgrading	2	No	
Webinar Rigol Advanced serial analysis webinar	Webinar for upgrading	1	No	
Life Member AG - IDROGENO VERDE: uno sguardo sul futuro energetico	Webinar for upgrading	3	No	
Unisa: "Gli Impianti di Climatizzazione e il Coronavirus"	Webinar for upgrading	2	No	

Il monitoraggio energetico in ambito industriale: l'esperienza lovato electric	Webinar for upgrading	1.5	No	
GRICU Ph.D. school on "Digitalization tools for the chemical and process industries"	Academic course for Hard skills	16	No	
6G: A New Frontier for the Design of NOMA	Webinar for upgrading	1	No	
Unisa: "Valorizzare i risultati della ricerca"	Webinar for upgrading	4.5	No	
BatterFly: Sistemi di Alimentazione Bidirezionali per le Industrie di Domani	Webinar for upgrading	1	No	
CEI: "Soluzioni e metodi per la disponibilità degli impianti elettrici"	Webinar for upgrading	4	No	
Think Green & Digital	Webinar for upgrading	2	No	
Energy Storage, Fotovoltaico ed Efficienza. Normativa, nuove soluzioni, case histories	Webinar for upgrading	2	No	
Protezione contro i fulmini e norme della serie 62305	Webinar for upgrading	4	No	
La sicurezza elettrica nelle macchine: la protezione contro i contatti diretti e indiretti	Webinar for upgrading	2.5	No	
Sicurezza stradale: Obiettivo zero vittime	Webinar for upgrading	1.5	No	
AEIT: L'era dell'idrogeno?	Webinar for upgrading	1.5	No	
MATHEGRAM: Research Methods and Science Communication	Webinar for upgrading	13	No	
"Cosa ci fanno due avvocati in mezzo a tutti quegli elettricisti?"	Webinar for upgrading	1	No	
Second year				
Energie rinnovabili e project financing oggi - seconda edizione	Webinar for upgrading	1	No	
Efficienza energetica dei campus universitari: la pianificazione energetica di Unisa	Webinar for upgrading	2	No	
Noi ingegneri industriali, tra competenze, etica e responsabilità	Webinar for upgrading	2	No	

Ripensare la mobilità con Federico testa - presidente ENEA	Webinar for upgrading	2	No	
Seminario online aeit sulle applicazioni elettriche navali: La sicurezza elettrica a bordo nave	Webinar for upgrading	5	No	
Equipaggiamento elettrico delle macchine	Webinar for upgrading	5	No	
Viaggio nell' E-Mobility italiano con FCA	Webinar for upgrading	2	No	
COMMS4ITALY: When Quantum-Signal Processing and Communications Meet...	Webinar for upgrading	1	No	
COMMS4ITALY: Sustainable ICT Greening ICT and Greening by ICT	Webinar for upgrading	1	No	
COMMS4ITALY: International Network Generations Roadmap (INGR)	Webinar for upgrading	1	No	
COMMS4ITALY: 5G Rules, who needs 6G?	Webinar for upgrading	1	No	
Learn the Latest Standards and Test Requirements for Automotive Radar	Webinar for upgrading	1	No	
Demystifying the Standards for Automotive Ethernet	Webinar for upgrading	1	No	
5G Network Slicing: Ensuring Successful Implementation and Validation	Webinar for upgrading	1	No	
Challenges and Solutions of Advanced Automotive Radar Design and Test Lifecycle	Webinar for upgrading	1	No	
Automotive Radar Fast Chirp System Analysis	Webinar for upgrading	1	No	
Power Converter Test Challenges in HEV	Webinar for upgrading	1	No	
Charging Test Challenges for Electric Vehicles	Webinar for upgrading	2	No	
5G NR Dynamic Spectrum Sharing (DSS): Overview and Test Challenges	Webinar for upgrading	1	No	
Four Key Steps to Meeting Energy Efficiency Requirements	Webinar for upgrading	1	No	
First year				
Ph.D. school: “Summer School on Smart Grid”	Academic course for Hard skills	28	YES	Pass

CEET	Academic course for Hard skills	96		
AIE	Academic course for upgrading	48		
English	Academic course for soft skills	48+20	Si	Pass
Cyber-Physical Systems	Academic lessons for upgrading	3	No	
Proton Therapy and related research activities at HZB	Academic lessons for upgrading	1	No	
Global Connectivity & Technolgy Organization	Academic lessons for upgrading	3	No	
Coordination of Autonomous Vehicles at Traffic Junctions: Theory and Experiments	Academic lessons for upgrading	2	No	
How much information can be deduced from a powder pattern?	Academic lessons for upgrading	2	No	
L'elettrificazione della mobilità e i sistemi di accumulo elettrico	Academic lessons for upgrading	3	No	
Rassegna sulle tecnologie al servizio della meteorologia	Academic lessons for upgrading	3	No	
Asset IQ: Internet of Things and Big Data applied to the Real Estate	Academic lessons for upgrading	2	No	
Energy Sustainability and Sustainable Energy Technologies	Academic course for Hard skills	4	Si	Pass
Smart Industry	Academic course for Hard skills	54	Si	Pass

Publications list:

a) Journal articles (please indicate the doi number)

b) Book chapters (please indicate the doi number, or, if not available, the ISBN of the volume)

c) Proceedings

d) Patents

e) Other