INTERUNIVERSITY PH.D. PROGRAM BETWEEN

POLITECNICO DI BARI AND UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

IN INDUSTRY 4.0

Mitigation of motion sickness in automated vehicles

PhD candidate

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Cycle

XXXVII

Tutors

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Description of the research program

Adoption of autonomous vehicles (AVs) can result in significant improvements in transportation safety, environmental impact and accessibility. However, there are several issues to be solved and concerns to be answered before AVs can be widely adopted by the public. Motion sickness (MS) is one of the major problems and is yet to be addressed. According to a survey conducted in many countries, 6-10% of adults riding an AV often experience a general or constant level of motion sickness (MS), whereas 6-12% experience severe MS. Therefore, for achieving broad acceptance of AVs, increasing their market penetration and delivering their socio-economic and environmental benefits, MS needs to be effectively addressed. To pursue this aim, the early stage of the research will consists of a literature review about the state-of-the-art of motion sickness models. Current tools for assessing passenger comfort (ride comfort) and MS include standardised metrics and models based on the direction, amplitude, frequency and duration of the accelerations experienced by the passengers. Comfort norms like ISO-2631-1, derived empirically by fitting mathematical functions to experimental data, have been used with some success to evaluate MS through the integration of frequency-weighted accelerations. However, the ISO norms lack any connection with the role of the vestibular system and are limited to one dimension (vertical motion). This project will also include a literature review about the models of vestibular system that can be included in the models of MS. As the aim is to alleviate MS in AVs by influencing the motion of the AV and this is determined by the path planning and path tracking layers of the decision making hierarchy, a literature review about the state of the art of path planning and path tracking techniques is needed. Actual on-line vehicle implementations of path planning algorithms use kinematic or simplified dynamic vehicle models, without any consideration of measures to mitigate MS. Recently, some studies started to point toward this direction and, some authors introduced MS mitigation, by including an MS metric within the cost function. However, the path planning problem is not fully addressed. A model to predict the incidence of MS is crucial to path planning and control for MS mitigation. Such a model could be derived from measurements of the motion exposure based on data, available in the literature, collected from both field and laboratory studies. This research proposal aims at exploring the effectiveness of mitigating MS in AVs, by using intelligent non linear model based and predictive control (NMPC), incorporating the MS models into the path planning and path tracking formulations. The developed strategies will be compared, implemented in real-time and, at last, these strategies will be tested on an autonomous vehicle.

Schedule of the research activities

First academic year (planned)

	Description	**Period**	**Activity abroad**
Literature survey and review	Literature survey and review on: - models of motion sickness; - models of vestibular system.	11/21 – 03/22	NO
Software implementation	Implementation on MATLAB-Simulink of models of motion sickness and models of vestibular system.	03/22 – 04/22	NO
Software implementation	Development and comparison of torque-vectoring controllers to enhance the stability of a car-trailer system with the possibility to include the motion sickness feature.	04/22 – 05/22	NO
Software implementation	Development and comparison of integrated torque-vectoring and traction control strategies with the possibility to include the motion sickness feature.	05/22 – 06/22	NO
Literature survey and review	Literature survey and review on: - path planning algorithm for autonomous vehicles;	06/22 – 10/22	NO

	- path tracking algorithm for autonomous vehicles.		

Second academic year (planned)

	Description	Period	Activity abroad
Software implementation	Implementation on MATLAB-Simulink of path planning and path tracking algorithms inclusive of motion sickness models	11/22 – 03/23	NO
Software implementation	Comparison of path planning and path tracking algorithms	03/23 – 07/23	NO
Real-time implementation	Real-time implementation of the proposed strategies	08/23 – 10/23	YES

Third academic year (planned)

	Description	Period	Activity abroad
Testing	Tests on experimental vehicle of the proposed strategies	11/23 – 06/24	YES
Thesis	Completion of the thesis	06/24 – 10/24	NO

Provisional training and research activities plan

Specify with the related CFU (ECTS) the training activities that you plan to carry out or have completed in the three years (e.g., courses to attend, conferences, seminars, etc.). Please refer to the *Educational regulations of the Doctoral School of Politecnico di Bari*: http://www.poliba.it/sites/default/files/dottorati/regscudopoliba.pdf

Specify with the related CFU (ECTS) the research activities that you plan to carry out in the three years (e.g., individual research activity, supervision of students, integrative seminars to be given by the PhD student, activity of manuscript preparation for conferences or journals, activity of patents preparation, etc.).

First academic year (planned)

	Description	Period	Duration	CFU
PhD courses	Dynamical behaviour of nonlinear structures, SSD: ING-IND/14	24/01/2022 – 02/02/2022	20 (h)	2
Master's degree courses	Model predictive control, SSD: ING-INF/04	First semester	60 (h)	6
	Meccanica delle vibrazioni, SSD: ING-IND/13	Second semester	60 (h)	6

	Meccanica del veicolo, SSD: ING-IND/13	Second semester	60 (h)	6
Participation to seminars and international congresses or workshops	Ciclo di seminari di ricerca interdisciplinare del DMMM	2022	–	2
Presentation of research products at international congresses or workshops				
	TOTAL OF CFU FOR TRAINING ACTIVITIES			22
Individual research activity	Literature review on motion sickness models, vestibular system models, path planning and path tracking algorithms	11/21 – 11/22	–	14
	Implementation on MATLAB-Simulink of motion sickness models, vestibular system models.	03/22 – 04/22	–	5
	Development of MATLAB code for torque-vectoring strategies	04/22 – 06/22	–	10
Students' supervision	Potential activities with students: laboratory activities, trainings, internships, thesis	11/21 – 10/22	–	2
Integrative didactive activities				
Preparation of manuscripts for conferences or journals	Preparation of a research article on the integration of motion sickness models with path planning and path tracking algorithm	3/22 – 10/22		7
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			38
	TOTAL OF CFU FOR YEAR I			**60**

Second academic year (planned)

	Description	**Period**	**Duration**	**CFU**
PhD courses				
Master's degree courses				
Massive Open Online Courses (MOOC)	Attending massive open online courses (MOOC)	–	–	6
Participation to seminars and	Participation to seminars for a total of 10 hours	–	10 (h)	3

international congresses or workshops	Participation to at least three congress or workshops	–	3 (d)	3
Presentation of research products at international congresses or workshops				
	TOTAL OF CFU FOR TRAINING ACTIVITIES			12
Individual research activity	Development of path planning and path tracking algorithms	11/22 – 03/23	–	11
	Comparison of path planning and path tracking algorithms	03/23 – 07/23	–	11
	Real-time implementation of path planning and path tracking algorithms	08/23 – 10/23	–	11
Students' supervision	Potential activities with students: laboratory activities, trainings, internships, thesis	11/22 – 07/23	–	6
Integrative didactive activities				
Preparation of manuscripts for conferences or journals	Preparation of a research article on the comparison of real-time implementable path planning and path tracking algorithms to mitigate motion sickness	03/23 – 10/23	–	9
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			48
	TOTAL OF CFU FOR YEAR II			**60**

Third academic year (planned)

	Description	**Period**	**Duration**	**CFU**
PhD courses				
Master's degree courses				
Participation to seminars and international congresses or workshops	Participation to seminars for a total of 10 hours	–	10 (h)	3
	Participation to at least three congress or workshops	–	3 (d)	3
Presentation of research products at international				

congresses or workshops				
	TOTAL OF CFU FOR TRAINING ACTIVITIES			6
Individual research activity	Experimental tests with the autonomous vehicle	11/23 – 06/24	–	28
Students' supervision	Potential activities with students: laboratory activities, trainings, internships, thesis	06/24 – 07/24	–	2
Integrative didactive activities				
Preparation of manuscripts for conferences or journals	Preparation of a research article on experimental results	06/24 – 10/24	–	10
Thesis	Completion of the thesis	06/24 – 10/24	–	14
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			54
	TOTAL OF CFU FOR YEAR III			**60**
	TOTAL OF CFU FOR THE WHOLE PHD COURSE			**180**