



UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II
SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

STUDY GUIDE

CORSO DI LAUREA MAGISTRALE (MASTER'S DEGREE)
IN AUTONOMOUS VEHICLE ENGINEERING (MOVE)

Classe delle Lauree Magistrali in Ingegneria Meccanica LM-33

ACADEMIC YEAR 2021/2022

Napoli, July 2021

Study course goals and employment opportunities

Surface, air and marine transport is today in a phase of profound transformation in order to include elements of greater autonomy. These elements of autonomy range from simple forms of enhanced control of a single vehicle to the complete execution of the mission, also in coordination with others, without any intervention by the human pilot.

The design of autonomous vehicles requires knowledge in different cultural areas, namely: modern industrial engineering and recent advances in information & communication technology.

The Master of Science (Laurea Magistrale - LM) in Autonomous Vehicle Engineering (MOVE) aims to train engineers with intercultural skills, who master themes such as:

- Design and management of autonomous land, air and sea transport systems,
- Fusion of information to make decisions in real time,
- Sensors and algorithms for driving, navigation and control with high autonomy level,
- Integration of the autonomous vehicle in complex environments.

Teaching is provided in English and a B2 certificate is required for enrollment.

The LM MOVE is a highly interdisciplinary study course because in order to operate in the autonomous vehicle world it is necessary to master information technology subjects, such as: control, machine learning, big data, data analytics, computer vision, internet of things, integrated transport, smart road, etc., as well as their applications to vehicles. To this end an adequate knowledge of vehicles design and operation is also needed. The profile of the engineer will therefore be that of an integrator of systems and technologies, able to operate in two fields of engineering: one more mechanical, namely transportation system dynamics and control, and the other more information technology oriented, in the sense of hardware and software requirement definition and integration for autonomous guidance and navigation.

The LM MOVE in the final phase includes three more characterized study plans:

- Self-driving cars,
- Autonomous aerial systems,
- Autonomous marine vehicles.

for each of them there is a design course is offered in which the acquired skills are integrated. The students will operate in industry-like groups, interacting on the various parts of the autonomous vehicle design, also with a view to enhancing team working and soft skills skill.

The LM MOVE offers extensive experimental activities in the various engineering laboratories of the University and many industry stage opportunities.

In addition to employment in the large, medium and small industries and in the research laboratories and spin offs operating in the autonomous vehicle engineering, thanks to the interdisciplinary profile of the LM MOVE, graduates will have good job opportunities in general, because they exceed a very frequent limit in today's master's degrees: that of training engineers with strong competences but very focused on a specific field. In the 4.0 industry world capability to integrate different disciplines with an intercultural approach, capability to master application of information and communication technologies to manufacturing and operation of mechanical systems will become an increasingly indispensable requirement.

Manifesto del corso di studio (anno accademico 2021-22)

Study program (academic year 2021-22)

Insegnamento (course)	Modulo (se presente)	Anno (year)	Semestre (semester)	CFU - ECTS	SSD	Tipologia (*)	Ambito disciplinare	Propedeuticità
Control Oriented Models for Vehicles Dynamics		1	1	6	ING-IND/13	2	Attività formative caratterizzanti	
Digital modelling of interactive systems and interfaces		1	1	6	ING-IND/15	2	Attività formative caratterizzanti	
Sensor Data Fusion and Measurement Uncertainty Management	Smart sensors and Measurement Uncertainty	1	1	6	ING-IND/12	2	Attività formative caratterizzanti	
	Sensor Data Fusion	1	2	6				
Guidance and navigation		1	1	6	ING-IND/05	4	Attività formative affini o integrative	
Control Architectures for Autonomous Driving	Control Systems for Autonomous Ground Vehicles	1	1	6	ING-INF/04	2	Attività formative caratterizzanti	
	Mobile Robots	1	2	6				
Machine Learning and Big data		1	2	9	ING-INF/05	2	Attività formative caratterizzanti	
Image and Video processing for autonomous driving		1	2	6	ING-INF/03	2	Attività formative caratterizzanti	
Laboratory of Autonomous Vehicle Design and Development	Autonomous Vehicle Simulation and Experimental Testing	2	1	6	ING-IND/13	2	Attività formative caratterizzanti	
	Concept design of new vehicles	2	2	6	ING-IND/15			
Insegnamenti specifici del percorso (v. tabelle sotto riportate) Electives (see tables below)		2		15		2 o 4	Attività formative caratterizzanti o affini o integrative	
Insegnamenti a scelta libera (v. tabelle sotto riportate) Electives (see tables below)		2		9		3	Attività formative a scelta autonoma dello studente	
Tirocinio/Ulteriori attività formative		2		12		6	Ulteriori attività formative	

Stage							
Prova finale Master thesis		2		15		5	Per la prova finale

(*) Legenda delle tipologie delle attività formative ai sensi del DM 270/04

Attività formativa	1	2	3	4	5	6	7
rif. DM270/04	Art. 10 comma 1, a)	Art. 10 comma 1, b)	Art. 10 comma 5, a)	Art. 10 comma 5, b)	Art. 10 comma 5, c)	Art. 10 comma 5, d)	Art. 10 comma 5, e)

Percorso *self-driving cars - self-driving cars study plan*

Insegnamento (course)	Modulo (se presente)	Anno (year)	Semestre (semester)	CFU - ECTS	SSD	Tipologia (*)	Ambito disciplinare	Propedeuticità
Power and Propulsion Systems for UV		2	2	9	ING-IND/08	2	Attività formative caratterizzanti	
Smart Roads and cooperative driving		2	2	6	ICAR/05	4	Attività formative affini o integrative	
Insegnamento suggerito per la scelta autonoma – Suggested elective								
Testing and validation of automated road vehicles		2	1	9	ICAR/05	3	Attività formative a scelta autonoma dello studente	

Percorso *unmanned aerial systems - unmanned aerial systems study plan*

Insegnamento (course)	Modulo (se presente)	Anno (year)	Semestre (semester)	CFU - ECTS	SSD	Tipologia (*)	Ambito disciplinare	Propedeuticità
Systems for autonomous aircraft		2	1	6	ING-IND/05	4	Attività formative affini o integrative	
Design of autonomous aircraft		2	2	9	ING-IND/05	4	Attività formative affini o integrative	
Insegnamento a scelta autonoma - Elective								
		2		9		3	Attività formative a scelta autonoma dello studente	

Percorso *unmanned marine vehicles* – *unmanned marine vehicles study plan*

Insegnamento (course)	Modulo (se)	Anno (year)	Semestre (semester)	CFU - ECTS	SSD	Tipologia (*)	Ambito disciplinare	Propedeuticità
Unmanned Marine Plants		2	1	6	ING-IND/02	4	Attività formative affini o integrative	
Design of Autonomous Marine Vehicles		2	2	9	ING-IND/01	4	Attività formative affini o integrative	
Insegnamento a scelta autonoma - Elective								
		2		9		3	Attività formative a scelta autonoma dello studente	

CONTROL ARCHITECTURES FOR AUTONOMOUS DRIVING - MODULE A: CONTROL SYSTEMS FOR AUTONOMOUS GROUND VEHICLES

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-INF/04	6	X			X			X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)	Prof. Stefania Santini			

COURSE OBJECTIVES

The course is intended to provide general knowledge about the design of current and next-generation control architectures for autonomous vehicles. Namely, it provides skills for designing intelligent ground vehicles, and related innovative applications in ITS and focuses on design, modeling, and control of highly interactive cyber-physical systems. In so doing, it integrates the expertise and attitude of modern industrial engineering topics (i.e., vehicles) with recent advances in ICT (i.e., AI/Control)

TABLE OF CONTENTS

- General Principles
 - Introduction to System Dynamics
 - Linear and Nonlinear Control Fundamentals
- Vehicle Control for autonomous and semi-autonomous driving
 - Trajectory planning and guidance
 - ADAS (Advanced Driving Assistance Systems)
 - Autonomous Driving Architectures leveraging sensors for environment detection
 - Adaptive Cruise Control (ACC)
- Cooperative Control for Autonomous Connected Vehicles
 - Cooperative Adaptive Cruise Control (CACC)
 - Internet-of-Vehicles (IoV) for Intelligent Transport Systems (ITS)
 - Networked cooperative control for connected autonomous cars/trains via V2X (Vehicle-to -Vehicles or Vehicle-to-Infrastructure) communication (e.g., via wireless networks or 4G/5G)
 - Platooning and Virtual coupling
 - I-ADAS at intersections
 - Cooperative Intersection Crossing
- Technologies for the development of smart vehicles in automotive and railway
 - Model-Based Control Design fundamentals
 - Modeling, Simulation and Test Methods for SIL and HIL validation of ADAS and autonomous driving strategies
 - Co-simulation platforms for evaluating the impact of smart and connected vehicles in homogenous and mixed traffic scenarios

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises.
 The teaching is structured in such a way as to provide the bases of theory, methodology and technology for the development of intelligent algorithms for achieving autonomous and semi-autonomous driving functionalities.
 Particular attention is paid to proposing practical experiences of the concepts learned. To this aim, the course also hosts lectures and seminars with experts from the industrial field. The final part of the Course activities follows a Challenge Based Learning (CBL) approach where students, divided in teams, are encouraged to take advantage of the learned tools to successfully tackle and solve a real problem posed by the latest technological developments in the field of intelligent and connected transport systems.

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks: Thor I. Fossen, Sensing and Control for Autonomous Vehicles: Applications to Land, Water and Air Vehicles (2017) Edition, ISBN-13: 978-3319553719, Springer International Publishing; J.J. E Slotine; Weiping Li, Applied nonlinear control, ISBN 0-13-040890-5. Prentice Education Ltd., 2005; Radovan Miucic, Connected Vehicles: Intelligent Transportation Systems (2019) 10.1007/978-3-319-94785-3 Springer International Publishing;

ASSESSMENT

Assessment will be	Written and Oral	<input checked="" type="checkbox"/>	Written Only	<input type="checkbox"/>	Oral only	<input type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests	<input type="checkbox"/>	Open questions	<input type="checkbox"/>	Numerical exercises	<input type="checkbox"/>
Other (es: project development, computer test ...)	Project development and computer test					

CONTROL ARCHITECTURES FOR AUTONOMOUS DRIVING - MODULE B: MOBILE ROBOTS

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-INF/04	6	X				X		X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The Mobile Robots course aims at presenting an overview of the tools employed to model, plan, and control autonomous ground mobile robots.

TABLE OF CONTENTS

<ul style="list-style-type: none"> • Introduction <ul style="list-style-type: none"> ○ General introduction about field and service robotics ○ Recap about differential geometry • Wheeled ground robots <ul style="list-style-type: none"> ○ Introduction ○ Nonholonomic constraints ○ Kinematic model ○ Chained form ○ Planning ○ Motion control ○ Odometric localization ○ SLAM algorithms • Motion planning <ul style="list-style-type: none"> ○ Canonical problem ○ Configuration space ○ Graph search algorithms <ul style="list-style-type: none"> ▪ Breadth-first ▪ Depth-first ▪ A* ○ Planning via retraction ○ Planning via cell decomposition <ul style="list-style-type: none"> ▪ Exact decomposition ▪ Approximate decomposition ○ Planning via artificial potentials • Robotic simulators <ul style="list-style-type: none"> ○ Robotic sensors, programming, and simulation ○ Robotic simulators like Gazebo and CoppeliaSim ○ Navigation and motion planning for mobile robots ○ Autonomous localization and mapping
--

EDUCATION METHOD

Lectures and seminars

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks: [1] B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, Robotics. Modelling, Planning and Control, Springer, 2009, ISBN 9781846286421 [2] J. Lentin, J. Cacace, Mastering ROS for Robotics Programming, 2nd edition, Packt Publishing, 2018, ISBN 9781788478953
--

ASSESSMENT

Assessment will be	Written and Oral <input type="checkbox"/>	Written Only <input type="checkbox"/>	Oral only <input checked="" type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests <input type="checkbox"/>	Open questions <input type="checkbox"/>	Numerical exercises <input type="checkbox"/>
Other (es: project development, computer test ...)	Technical project development		

CONTROL ORIENTED MODELS FOR VEHICLE DYNAMICS

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/13	6	X			X			X

Required/expected prior knowledge: Fundamentals of Calculus, General and Applied Physics, and Industrial Engineering Drawing

Class(es)				
Teacher(s)	Mario Terzo			

COURSE OBJECTIVES

The course aims to provide the fundamental knowledges for the synthesis of physical-mathematical models of mechanical systems according to an approach that is functional to the design of the model-based controllers. The methodologies for modelling, the main sources of mechanical nonlinearities, as well as local linearization based tools are described, starting from the typical features of the mechanical systems, with particular reference to vehicle dynamics.

TABLE OF CONTENTS

Systemic approach for the design of a mechanical system: mechatronic system; passive, semi-active and active controls; feedforward and feedback controls
 Modelling of mechanical systems: d'Alembert and Newton approaches, Lagrange approach, linear time-invariant mechanical systems, nonlinearities in mechanical systems, linearization technique
 State-space modelling, input-output modelling, transfer function, Laplace domain, Laplace transform, stability analysis
 Control of mechanical systems in terms of vibrational characteristics
 Longitudinal and lateral dynamics of road and railway vehicles
 Control of the dynamics of road and railway vehicles

EDUCATION METHOD

(specificare eventuali modalità (sviluppo progetti, presentazioni, lavori di gruppo, uso software specifici) in aggiunta alla didattica tradizionale)

Lessons, numerical exercises with dedicated softwares

TEXTBOOKS AND LEARNING AIDS

Vehicle dynamics and control, R. Rajamani, Springer Ed.
 Handbook of railway vehicle dynamics, S. Iwnicki, CRC Press

ASSESSMENT

Assessment will be	Written and Oral	<input type="checkbox"/>	Written Only	<input type="checkbox"/>	Oral Only	<input checked="" type="checkbox"/>
In case of written assessment, questions are	Multiple choicetests	<input type="checkbox"/>	Open questions	<input type="checkbox"/>	Numerical exercises	<input type="checkbox"/>
Other (es: project development, computer test ...)						

DESIGN OF AUTONOMOUS AIRCRAFT

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/05	9		X		X			X

Required/expected prior knowledge: NONE

Class(es)			
Teacher(s)			

COURSE OBJECTIVES

The course is intended to provide a basic knowledge about architecture and operation of Unmanned Aircraft Systems (UAS) and More Autonomous Aircraft. Special emphasis is given to interactive development of a practical application of Autonomous Aircraft Design. It can be related to the development of a specific aircraft or to the realization of a specific subsystem for a customized application.

TABLE OF CONTENTS

First Part – Selected topics
 UAS Configurations and Applications: Military & Civilian Roles. Evolution, current and future systems.
 More Autonomous Aircraft.
 UAS Payloads: radar, electro-optical, other sensors
 UAS ground stations and human factors, levels of automation, mission planning systems.
 Regulations and airspace integration.
 Small UAS and UTM framework.
 Urban Mobility.

Second Part – Design Application Example
 One or more Autonomous Aircraft Design distinctive examples will be selected. Their preliminary design will be discussed and developed interactively by students and teacher, following the typical certified development process carried out in an Aerospace Company.

EDUCATION METHOD

Lectures, development of test case, learning by doing.

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
 J. Gundlach, Designing Unmanned Aircraft Systems: A Comprehensive Approach, AIAA Education Series, 2012
 R. Austin, Unmanned Aircraft Systems: UAVs Design, Development and Deployment, Wiley, 2010
 R.W. Beard, T.W. McLain, Small Unmanned Aircraft: Theory and Practice, Princeton University Press, 2012
 R.W. Beard, Quadrotor dynamics and control, lecture notes, 2008
 S. Blackman, R. Popoli, Design and analysis of modern tracking systems, Artech House, 1999.
 R.C. Nelson, Flight Stability and Automatic Control, McGraw Hill, 1998

ASSESSMENT

Assessment will be	Written and Oral	<input type="checkbox"/>	Written Only	<input type="checkbox"/>	Oral only	<input checked="" type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests	<input type="checkbox"/>	Open questions	<input type="checkbox"/>	Numerical exercises	<input type="checkbox"/>
Other (es: project development, computer test ...)						

DESIGN OF AUTONOMOUS MARINE VEHICLES

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/01	9		X			X		X

Required/expected prior knowledge: _NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides an overview of different types of Marine Autonomous Vehicles, highlighting trends and future developments. References and skills for hull-form definition, motion resistance and horsepower assessment are given. Static and dynamic stability are analyzed and evaluated through simplified approaches and available sw. Seakeeping, Dynamic positioning, and Maneuverability performances of AMV are considered in the frame of the design procedure to get students ready to perform a preliminary AMV design as final Thesis.

TABLE OF CONTENTS

- - Types of AMV and different mission profiles
 - Unmanned merchant ships and shuttles
 - Unmanned marine vehicles for data acquisition
 - Unmanned marine vehicles for Navies
- - Measurement uncertainty estimation according to GUM Data-base analysis and Design procedure
- - Hydrodynamic performance and horsepower assessment
- - Propulsion and energy storage for small size AMV
- - Static stability, theory and evaluation
- - Dynamic stability aspects, self-righting and surviving capabilities for small size AMV
- - AMV behavior at sea, seakeeping
- - Design features for Dynamic Positioning
- - Maneuverability of AMV
- - Hull-forms for small AMV
- - Tank testing for AMV
- - Regulatory frame

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities.

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
 Roberts G.N. and Sutton R., Further Advances in Unmanned Marine Vehicles– Control Engineering Series, 2012

ASSESSMENT

Assessment will be	Written and Oral <input type="checkbox"/>	Written Only <input type="checkbox"/>	Oral only <input checked="" type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests <input type="checkbox"/>	Open questions <input type="checkbox"/>	Numerical exercises <input type="checkbox"/>
Other (es: project development, computer test ...)	Project development and computer test		

DIGITAL MODELLING OF INTERACTIVE SYSTEMS AND INTERFACES

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/15	6	X			X			X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)	Di Gironimo G.	Patalano S.		

COURSE OBJECTIVES

To achieve technical skill about part and system modelling. To manage CAD-CAE model in a PDM platform. To develop multidomain models using MATLAB environment. To provide the student with the fundamentals of VR/AR technology.

To know methods for Usability studies, Interaction Analysis and HMI evaluation.

TABLE OF CONTENTS

- Virtual prototyping.
 - CAD assembly and Product Data Management.
 - From CAD to VR.
- Human modeling and usability evaluation.
 - Introduction to Virtual and Augmented Reality.
 - Stereoscopic Vision, input and output devices.
 - Indexes of usability for HMI.
- Applications of Design Review in railways, automotive, aeronautics and naval fields (3 CFU)
- Multidomain modeling principles
 - Definition of generalised variable in complex systems.
 - Power and energy variables in different domains.
- Bond-Graph representation.
 - Elements of a bond-graph.
 - Computational causality.
 - Energy storage elements.
 - Resistors and Sources.
 - Transformers and Gytrators.
 - Basic rules for building and analyzing power transmissions.
- Object oriented mathematical modelling.
 - Classes and instances.
 - Inheritance.
 - Generic classes.
 - Equations.
 - Acausal physical modelling.
 - Component model.
 - Component design library and use.
- Multi-body modelling.
- Model Simulation in MATLAB Simscape environment.
- Multiobjective optimization. (3 CFU)

EDUCATION METHOD

(specificare eventuali modalità (sviluppo progetti, presentazioni, lavori di gruppo, uso software specifici) in aggiunta alla didattica tradizionale)

Lectures, tutorials, laboratory activities and exercises.

CAD/CAE, PLM and virtual prototyping tools are used at the Fraunhofer JL Ideas and Ergos and Marte lab at CESMA in San Giovanni. Learning by doing.

TEXTBOOKS AND LEARNING AIDS

Course materials.
 MATLAB suite available for UNINA students.
 Dathan B., Ramnath S., Object-Oriented Analysis, Design and Implementation, Springer, 2nd ed., 2015, ISBN 978-3-319-24280-4.

ASSESSMENT

Assessment will be	Written and Oral	<input checked="" type="checkbox"/>	Written Only	<input type="checkbox"/>	Oral only	<input type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests	<input type="checkbox"/>	Open questions	<input type="checkbox"/>	Numerical exercises	<input type="checkbox"/>
Other (es: project development, computer test ...)	Project work during the semester discussed with an internal committee. Communication and presentation of the work using many software tools. Presentation of virtual prototypes.					

GUIDANCE AND NAVIGATION

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/05	6	X			X			X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course is intended to provide the needed knowledge to design and develop efficient guidance and navigation solutions for autonomous vehicles. Guidance is the development of the mission plan, i.e. the 3D or 4D trajectory for the vehicle, depending on the type of transport systems. Guidance can be strategic or tactical depending whether it is realized before the mission is started or not. Navigation is the function that provides information about position, velocity, and orientation for the vehicle. It is accomplished by integrating measurement from different sources, such as sensors and receivers.

TABLE OF CONTENTS

- Introduction. Definitions and principles.
- System architecture of mission management for autonomous vehicles.
- Guidance
 - Requirements and constraint for mission planning;
 - Strategic path planning;
 - Tactical path planning. Dubin's paths;
 - Real-time mission planning management;
- Navigation
 - Reference terms for terrestrial navigation;
 - Process sensors: inertial systems
 - Reference configurations for inertial navigation;
 - Traditional inertial sensors;
 - Advanced inertial sensors;
 - Coriolis gyros;
 - Fiber optic gyros;
 - MEMS inertial sensors;
 - Inertial Navigation Equations;
 - Error of Inertial Navigation;
 - Basic models of measurement sensors;
 - Satellite navigation;
 - Integrated navigation
 - Architecture of integrated navigation systems;
 - Integrated navigation by Kalman Filtering
 - Reference model;
 - Application – GPS/INS integration.

EDUCATION METHOD

Lectures, interactive tutorials, exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
 Farrell J. and Barth M., "The Global Positioning System and Inertial Navigation", McGraw Hill, New York NY, USA, 1999
 Savage P.G., Strapdown Analytics, Strapdown Associates Inc., Maple Plain MN, USA, 2000
 Rogers R. M., "Applied Mathematics in Integrated Navigation Instruments", AIAA Press, Washington DC, USA, 2000
 Titterton, D. H., "Strapdown Inertial Navigation Technology", Peter Peregrinus, New York NY, USA, 1996

ASSESSMENT

Assessment will be	Written and Oral <input type="checkbox"/>	Written Only <input type="checkbox"/>	Oral only <input checked="" type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests <input type="checkbox"/>	Open questions <input type="checkbox"/>	Numerical exercises <input type="checkbox"/>
Other (es: project development, computer test ...)			

IMAGE AND VIDEO PROCESSING FOR AUTONOMOUS DRIVING

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-INF/03	6	X				X		X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

Aim of this course is to provide conceptual and practical tools to solve computer vision problems, with special focus on autonomous driving vehicles.

TABLE OF CONTENTS

Basic concepts on images and video signal. Spatial domain processing: histogram modification, geometric operations, morphological filtering, linear filtering, clustering, segmentation, classification. Fourier transform and filtering in the Fourier domain. Local and global descriptors. Dense and keypoint based matching techniques. Object tracking. Estimation of optical flow and motion field. Stereo vision. 3D reconstruction of the scene. Approaches based on deep learning for object recognition. Detection and localization of objects by semantic segmentation.

EDUCATION METHOD

Lectures, laboratory activities

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
 Rafael C. Gonzalez and Richard Woods, Digital Image Processing, Fourth Edition, Pearson, 2018.
 Richard Szeliski, Computer Vision – Algorithms and Applications, Springer, 2010.

ASSESSMENT

Assessment will be	Written and Oral	X	Written Only		Oral only	
In case of written assessment, questions are	Multiple choice tests		Open questions		Numerical exercises	
Other (es: project development, computer test ...)	Project development and computer test					

LABORATORY OF AUTONOMOUS VEHICLE DESIGN AND DEVELOPMENT (LoVeD)

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/13	6		X		X			X
ING-IND/15	6							

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)	Lanzotti A.	Renno F.	Savino S.	Strano S.

COURSE OBJECTIVES (teoriche e pratiche)

To achieve creative and technical skill about system integration of new autonomous vehicles from new ideas to functional simulation. To know methods for concept generation and concept selection, evaluating and improving usability and safety. To face real problem of AV innovation.
 To provide the student with the fundamentals of motion planning and control of mechanical systems to develop a system with autonomous guidance.
 Development of autonomous vehicle prototypes through simulations and experimental tests.

TABLE OF CONTENTS

I) Concept design of new vehicle (ING-IND/15)

- The product design and development process from an innovative idea to functional prototype.
- Design principle: Axiomatic Design theory.
- Systematic approaches to innovation
 - TRIZ tools to enhance creativity into design process.
- International Patent Classification. (3 CFU)
- Methods for functional requirement definition and development.
 - Model-Based Systems Engineering (MBSE) approach to the designing of smart mechanical systems.
 - UML e SysML.
 - Black Box & White Box Analysis.
 - Directed graphs and Functional modelling.
- Functional Requirement Definition.
- User centered design of smart systems. (3 CFU)

II) Autonomous Vehicle Simulation and Experimental testing (ING-IND/13)

- Motion planning.
- Laws of motion and trajectories. Elementary laws of motion. Criteria for choosing the laws of motion.
- Minimum actuation time. Scaling of the laws of motion.
- Planning of laws of motion and trajectories of a mobile system.
- Path following and Trajectory tracking.
- Laboratory experiences to visualize the trajectories. (3CFU)
- Integration between sensors and autonomous vehicles.
- Vision systems in motion planning applications.
- Simulations and experimental verifications of autonomous driving control strategies.
- Laboratory experiences. (3CFU)

EDUCATION METHOD

(specificare eventuali modalità (sviluppo progetti, presentazioni, lavori di gruppo, uso software specifici) in aggiunta alla didattica tradizionale)

The teamwork experience contributes the developing of new creative ideas that are submitted to a participatory evaluation to win a classroom contest. Communication skill, open discussion with stakeholders. The project evaluation is carried out both by a panel of internal experts and a jury of students. CAD/CAE and virtual prototyping tools are used. Learning by doing.

TEXTBOOKS AND LEARNING AIDS

Ullrich - Eppinger, *Product design and development*, V ed., Mc Graw Hill, 2011.
 Rossi C., *Lezioni di Meccanica dei Robot*, Edizioni scientifiche ed artistiche, 2012.
 Rossi C., *Brain, Vision and AI*, IN-TECH, 2008.
 Hall E., *Advances in Robot Manipulators*, IN-TECH, 2010.
 Course materials.

ASSESSMENT

Assessment will be	Written and Oral	X	Written Only		Oral only	
In case of written assessment, questions are	Multiple choice tests		Open questions		Numerical exercises	
Other (es: project development, computer test ...)	Project development during the semester discussed with an internal and external committee. Communication and presentation of the work using many software tools. Presentation of the virtual and physical prototype.					

MACHINE LEARNING AND BIG DATA

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-INF/05	9	X				X		X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The aim of the course is to present the main machine learning techniques, covering all aspects from data preparation to performance evaluation, through practical exercises carried out with commercial and/or open source tools. An introduction to Big Data and Data Analytics lifecycle is also provided, with reference to the design of large and complex databases, and to the process of modeling, acquiring, sharing, analyzing and visualizing the information embedded into Big Data.

TABLE OF CONTENTS

Data Mining and Machine Learning. Knowledge representation: Trees, Rules, Clusters.
 Basic Machine Learning methods: Statistical Modeling, Linear Models, Instance based learning, Clustering.
 Performance Evaluation: Cross-Validation, Cost-sensitive classification, ROC curves.
 Advanced Machine Learning: Decision Trees, Support Vector Machines, MLP, Bayesian Network, Hierarchical Clustering, EM, Semisupervised Learning.
 Data transformation: attribute selection, PCA, Sampling, Cleansing.
 Deep Learning: training and performance evaluation of Deep Networks, Convolutional Neural Networks. Introduction to database systems. Definition of a Big Data system. Data model for Big Data. The Hadoop ecosystem. Yarn. Pig. Hive. Giraph. Spark. NoSQL database: Key-value - Column-family, Graph database systems.
 Introduction to Big Data Analytics (BDA): BDA Lifecycle: knowledge discovery in database, data preparation, model planning, model building, data visualization.
 Examples of commercial and open source Tools: Oracle, IBM Business Analytics, Microsoft Power BI, Microsoft Azure. AWS. SAP Hana

EDUCATION METHOD

Lectures and laboratory activities

TEXTBOOKS AND LEARNING AIDS

Data mining: practical machine learning tools and techniques.— 4th ed. / Ian H. Witten, Frank Eibe, Mark A. Hall, Christopher J. Pal —The Morgan Kaufmann, 2017.
 Mining of Massive Datasets”, J. Leskovec, A. Rajarman, J.D.Ullman, 2014 (on line book)

ASSESSMENT

Assessment will be	Written and Oral	Written Only	Oral only	X
In case of written assessment, questions are	Multiple choice tests	Open questions	Numerical exercises	
Other (es: project development, computer test ...)	Project development			

POWER AND PROPULSION SYSTEMS FOR UV

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/08	9							X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course is focused on the conceptual design and practical assembly of power generation and propulsion units as applied to land Unmanned Vehicles, with particular reference to automotive applications. The devices, differentiated by the range of hybridization and/or the architecture of the drive-train, are analyzed on the basis of weight, size, endurance, safety, environmental impact and reliability issues. The vehicle energy management is also addressed in some details.

TABLE OF CONTENTS

- Classification of powertrains for UV
- State-of -the art SI and CI ICE
- Basics of Fuel Cell in propulsion applications
- Thermal/ electric hybrid systems
- On board energy and power needs
- Integration, configuration and control of the power-train components
- Fundamentals of powertrain design
- Numerical tools for powertrain control and management

EDUCATION METHOD

Lectures and laboratory activities

TEXTBOOKS AND LEARNING AIDS

Slides, technical papers. Textbooks:
 J.B. Heywood, Internal combustion engine fundamentals, McGraw-Hill Education, 2018, ISBN: 9781260116106.
 L. Guzzella, A. Sciarretta, Vehicle Propulsion Systems, Springer-Verlag Berlin Heidelberg, 2005, doi: 10.1007/3-540-28853-8.
 A. Taghavipour, M. Vajedi, N. Azad, Intelligent Control of Connected Plug-in Hybrid Electric Vehicles, Springer International Publishing, 2019, doi: 10.1007/978-3-030-00314-2.
 S. Onori, L. Serrao, G. Rizzoni, Hybrid Electric Vehicles, Springer-Verlag London, 2016, doi: 10.1007/978-1-4471-6781-5.

ASSESSMENT

Assessment will be	Written and Oral	<input type="checkbox"/>	Written Only	<input type="checkbox"/>	Oral only	<input checked="" type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests	<input type="checkbox"/>	Open questions	<input type="checkbox"/>	Numerical exercises	<input type="checkbox"/>
Other	Project development					

SMART SENSORS AND MEASUREMENT UNCERTAINTY

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/12	6	X			X			X

Required/expected prior knowledge: _____

Class(es)			
Teacher(s)			

COURSE OBJECTIVES

The course is intended to provide the general knowledge about measurement systems and sensors as well as their metrological characteristics, both static and dynamic in order to point out the main specifications needed to define the best solution according to the required target. Moreover, uncertainty estimation in direct and indirect measurements according to the current recommendation has to be mastered by the students. Finally, embedded systems and microcontroller will be presented along with the main integrated development environments for the implementation of firmware.

TABLE OF CONTENTS

- General principles
 - General measurement system
 - Static characteristics of measurement system elements
 - Accuracy of measurement systems in the steady state
 - Dynamic characteristics of measurement systems elements
- Measurement uncertainty estimation according to GUM
 - Fundamentals of statistics and probability
 - A-type and B-type estimation of uncertainty in direct measurements
 - Measurement uncertainty estimation in indirect measurements according to JCGM 100:2008
 - Propagation of distributions using a Monte Carlo method according to JCGM 101:2008
 - Extension to any number of output quantities according to JCGM 102:2011
- Basic models and operating principle of main sensors
 - Temperature sensors
 - Pressure sensors
 - Accelerometers
 - Gyroscopes
 - Magnetometers
 - Linear and angular encoders
 - MEMS technology for measurement sensors
- Implementation on embedded systems
 - Overview on embedded systems
 - Overview on main microcontrollers architectures
 - Register level programming of ARM-based microcontrollers
 - General input/output ports;
 - Timers;
 - Analog to digital converters
 - Digital to analog converters
 - Short range communication protocols
 - Universal Synchronous-Asynchronous Receiver/Transmitter
 - Inter Integrated Circuit
 - Serial Peripheral Interface
 - Direct memory access;

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
 Jitendra R. Raol, Multi-sensor data fusion with Matlab, CRCPress, Boca Raton FL, USA, 2010
 H.B. Mitchell, Multi-Sensor Data Fusion – An Introduction, Springer, 2007
 P. Groves, Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, 2008
 John P. Bentley, Principles of Measurement Systems, Pearson Education Limited, Edinburgh, 2005
 S.C. Mukhopadhyay, K. P. Jayasundera, O.A. Postolache - Modern Sensing Technologies, Springer, 2019
 Microcontroller, sensors, GNSS and radar datasheets, user and reference manuals.

ASSESSMENT

Assessment will be	Written and Oral <input checked="" type="checkbox"/>	Written Only <input type="checkbox"/>	Oral only <input type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests <input type="checkbox"/>	Open questions <input type="checkbox"/>	Numerical exercises <input type="checkbox"/>
Other (es: project development, computer test ...)	Project development and computer test		

SENSOR DATA FUSION

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/12	6	X				X		X

Required/expected prior knowledge: _____

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course is intended to present, from both theoretical and experimental point of view, methods and algorithms for acquired data processing. Moreover, particular attention will be paid to the real-time data transmission and processing from the smart sensor realized by means of an embedded system and an external high-performance computational unit, such as digital signal processor or personal computer. This way, it will be possible for the students to accomplish the main objective of the course, i.e. the definition, implementation and metrological characterization of an integrated measurement system involving IMU, GNSS and radar.

TABLE OF CONTENTS

- Theoretical fundamentals of multi-sensors data fusion procedure
 - Data fusion Models
 - Kalman filter
 - Extended Kalman filter
 - Unscented Kalman filter
 - Particle filter
 - Basics of heuristic approaches
 - Basics of machine and deep learning approaches
- Fundamentals of radio and radar systems
 - Main elements of a general radiocommunication system
 - Antennas and budget equation
 - Typical long/medium/short range communication protocols
 - Main elements of a general radar system
 - Radar operating principle
 - Radar operating frequencies
- Implementation on embedded systems
 - Data acquisition from external sensors
 - Sensors daughter boards
 - MEMS inertial measurement unit
 - Global navigation satellite system
 - Multi-sensors data fusion
 - Data integration among IMU, GNSS and radar
 - Examples of Kalman filter implementation
 - Examples of Extended Kalman filter implementation
 - Examples of Unscented Kalman filter implementation
 - Measurement uncertainty estimation
 - A-type and B-type estimation of uncertainty of raw data
 - Measurement uncertainty estimation of filter outputs

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
 Jitendra R. Raol, Multi-sensor data fusion with Matlab, CRCPress, Boca Raton FL, USA, 2010
 H.B. Mitchell, Multi-Sensor Data Fusion – An Introduction, Springer, 2007
 P. Groves, Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, 2008
 John P. Bentley, Principles of Measurement Systems, Pearson Education Limited, Edinburgh, 2005
 S.C. Mukhopadhyay, K. P. Jayasundera, O.A. Postolache - Modern Sensing Technologies, Springer, 2019
 Microcontroller, sensors, GNSS and radar datasheets, user and reference manuals.

ASSESSMENT

Assessment will be	Written and Oral <input checked="" type="checkbox"/>	Written Only <input type="checkbox"/>	Oral only <input type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests <input type="checkbox"/>	Open questions <input type="checkbox"/>	Numerical exercises <input type="checkbox"/>
Other (es: project development, computer test ...)	Project development and computer test		

SMART ROADS AND COOPERATIVE DRIVING

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ICAR/05	6		X					X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

The course provides students with a clear and deep understanding of the technical and functional requirements to be satisfied for vehicle/road interaction under connected and automated driving scenarios.

TABLE OF CONTENTS

- General Principles
 - Autonomous driving and cooperative driving
 - From autonomous driving to automated driving
 - Historical overview of autonomous/automated driving development for surface vehicles and state of the art
- Cooperative-Intelligent Transportation Systems platforms and services
 - Opportunities, criticalities, regulation and technical/functional requirements
 - Road-side implementation of cooperative driving
 - On-board implementation of cooperative driving
 - European C-ITS platform and services
 - Day 1 services and further services
 - Overview of specific (cyber)security issues
- Impacts on vehicular traffic
 - Automated, connected and mixed traffic
 - Interaction of connected vehicles and automated vehicles with existing transportation systems
 - Interaction and synergies with Mobility-as-a-service solutions
- Design of cooperative-driving solutions and mobility solutions in a simulation environment

EDUCATION METHOD

Lectures, laboratory activities and exercises.
Particular attention is paid to proposing practical applications of the concepts learned; to this aim, the course also hosts lectures and seminars with experts from the field of road and traffic operators and authorities.

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers, regulation documents.

ASSESSMENT

Assessment will be	Written and Oral	<input checked="" type="checkbox"/>	Written Only	<input type="checkbox"/>	Oral only	<input type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests	<input checked="" type="checkbox"/>	Open questions	<input type="checkbox"/>	Numerical exercises	<input checked="" type="checkbox"/>
Other (es: project development, computer test ...)						

SYSTEMS FOR AUTONOMOUS AIRCRAFT

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/05	6		X		X			X

Required/expected prior knowledge: NONE

Class(es)				
Teacher(s)				

COURSE OBJECTIVES

This course will teach students the operating principles of main components of onboard avionics for last-generation aircraft with increased autonomy capabilities. The most important concepts regarding design and integration issues will be discussed. The main topics discussed in the course can be summarized as follows:

- i) Data buses;
- ii) Communications;
- iii) Navigation;
- iv) Surveillance.

TABLE OF CONTENTS

1. Onboard system for more autonomous aircraft.
2. ATM system overview and basic operations.
3. Advanced cockpit - Displays and indicators.
4. Data buses: ARINC 429, ARINC 629, MIL 1553B.
5. Communications
 - a. Regulations and standards for aeronautical radio communications;
 - b. Voice radio links;
 - c. Data radio links.
6. Navigation
 - a. Inertial Units for Aircraft;
 - b. Air Data Systems;
 - c. Radio Navigation Aids: NDB, ADF, VOR, TACAN, DME, RNAV;
 - d. Doppler Radar;
 - e. Instrument Landing System;
 - f. GNSS for Aeronautics;
 - g. Performance Based Navigation;
7. Surveillance and Situational Awareness
 - a. Ground infrastructure (radars and ground control centers);
 - b. Onboard systems (transponders);
 - c. ADS-B;
 - d. ACAS and TCAS;
 - e. GPWS;
 - f. TAWS.

EDUCATION METHOD

Lectures, interactive tutorials, exercises

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers. Textbooks:
 Nolan, M.,S., Fundamentals of Air Traffic Control, Cengage Learning;
 Kayton, M. and Fried, W.R., Avionics Navigation Systems, Wiley-Interscience;
 Spitzer, C.R., and Ferrel, U., Digital Avionics Handbook, CRC Press;
 Helfrick, A., Principles of Avionics, Avionics Communications Inc.;
 Ashford, N.J., Stanton, H.P.M., and Moore, C.A., Airport Operations, McGraw-Hill Professional Publishing;

Tooley, M. and Wyatt, D., Aircraft Communications and Navigation Systems. Principles, Maintenance and Operation, Routledge;
 Stacey, D., Aeronautical Radio Communication Systems and Networks, John Wiley and Sons.

ASSESSMENT

Assessment will be	Written and Oral <input type="checkbox"/>	Written Only <input type="checkbox"/>	Oral only <input checked="" type="checkbox"/>
In case of written assessment, questions are (*)	Multiple choice tests <input type="checkbox"/>	Open questions <input type="checkbox"/>	Numerical exercises <input type="checkbox"/>
Other (es: project development, computer test ...)			

TESTING AND VALIDATION OF AUTOMATED ROAD VEHICLES

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ICAR/05	9		X					X

Required/expected prior knowledge: NONE

Class(es)			
Teacher(s)			

COURSE OBJECTIVES

The course provides students with theoretical and technical skills for the validation of automated vehicles in simulation environments

TABLE OF CONTENTS

- Definition of testing and validation scenarios
- Automation levels, use cases and operational design domain
- Traffic modelling
 - Static vs. adaptive/responsive approaches
 - Traffic micro-simulation, integration of detailed vehicle logics and nano-simulation approaches
 - Integration of adaptive/responsive traffic models in complex vehicle-simulation environments
- Adoption of vehicle-automation logics and integration in the modelling framework
 - Model-in-the-loop framework
 - Integration with traffic operator services
 - Integration with driving simulation environments
- Testing strategies
 - Use case vs. continuous testing
 - Sensitivity analysis
- Experiences and experiments

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and case studies

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers.

ASSESSMENT

Assessment will be	Written and Oral <input type="checkbox"/>	Written Only <input type="checkbox"/>	Oral only <input checked="" type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests <input type="checkbox"/>	Open questions <input type="checkbox"/>	Numerical exercises <input type="checkbox"/>
Other (es: project development, computer test ...)			

UNMANNED MARINE PLANTS

SSD	CFU	Year (I, II or III)			Semester (I or II)		Language	
		I	II	III	I	II	Italian	English
ING-IND/02	6		X		X			X

Required/expected prior knowledge: _____

Class(es)			
Teacher(s)			

COURSE OBJECTIVES

The course aims to provide the student with the basic knowledge of the propulsion and auxiliary systems of marine vessels with particular reference to automatic management. Furthermore, notions will be provided for the integration of these devices with each other, with navigation systems and remote control station. Safety and regulatory issues will also be considered in the course. Energy Storage aspects and natural energy sources on board are considered in detail. Students will be given indications to use a simulator in dedicated software environment and elements and techniques of energy assessment for a given mission profile.

TABLE OF CONTENTS

- - Description of the architecture and operation of propulsion systems, electric power generation and auxiliary systems for machinery load and hull systems;
- - Control of the propulsion motor (automatic start, speed control, fault management);
- - Control of the electric power generation plant (management of start and stop sequences, frequency regulation, active and reactive power, management of electrical loads and safety procedures during power black-out);
- - Automatic management of auxiliary systems for propulsion and electrical generation systems;
- - Control of the steering plant and interface with navigation systems;
- - Principles inspiring current rules for ships with automatic systems and future evolution;
- - Main components for electric propulsion of small craft;
- - Energy storage, type of batteries and other energy sources;
- - Energy sources for long range vehicles.

EDUCATION METHOD

Lectures, interactive tutorials, laboratory activities and case studies

TEXTBOOKS AND LEARNING AIDS

Slides, lecture notes, technical papers.

ASSESSMENT

Assessment will be	Written and Oral	<input type="checkbox"/>	Written Only	<input type="checkbox"/>	Oral only	<input checked="" type="checkbox"/>
In case of written assessment, questions are	Multiple choice tests	<input type="checkbox"/>	Open questions	<input type="checkbox"/>	Numerical exercises	<input type="checkbox"/>
Other (es: project development, computer test ...)	Project development and computer test					

Minimum curricular requirements to enroll in LM MOVE

For enrollment in the Laurea Magistrale LM (Master of Science) in Autonomous Vehicle Engineering MOVE possession of one of the following two qualifications is required:

1. Three-years degree in industrial engineering (Italian L-9 class) or information engineering (Italian L-8 class).
2. Three-years degree in other scientific or technological degree classes in Italy (L-7 Civil and environmental engineering, L-30 Physical sciences and technologies, L-31 Information sciences and technologies, L-35 Mathematical sciences) or qualification obtained at abroad (for example BS or BEng) in the scientific or technological field as long as it is recognized suitable by the Didactic Coordination Commission. The passing of a minimum number of 36 CFU (ECTS) in the following scientific disciplines must be guaranteed: INF/01 - Computer Science, ING-INF/05 - Information processing systems, MAT/03 - Geometry, MAT/05 - Calculus, FIS/01 - Experimental physics.

Knowledge of English is required for access, at least at a level comparable to B2 of the European Framework of Reference for Languages with certification issued by the University or by an accredited body.

The Didactic Coordination Commission also disciplines, according to guidelines established uniformly for all the Master's Degree Courses in Engineering of the Polytechnic School and the Basic Sciences, the methods for verifying the adequacy of the student's personal preparation.

- With reference to the qualifications referred to in the above case 1, students fulfill personal preparation check when the average grade is not less than 24/30. Requests for admission to the MOVE Master of Science by students failing the above criterion for automatic admission will be examined by the Didactic Coordination Commission which will assess the admissibility of the request with unquestionable judgment, establishing any requirements to be fulfilled by the interested student for the admission to the Master of Science program. As an example the Commission will examine the curriculum followed by the interested student, possibly taking into consideration the marks of profit achieved in characterizing courses or in courses considered in any case of particular relevance for the successful conduct of the Master's degree program, or will prepare assessment methods (interviews, test) to verify the adequacy of the student's personal preparation, or will adopt mode C (see below) provided for the curricular additions in the above case 2.
- With reference to the qualifications referred to in the above case 2, the Didactic Coordination Commission evaluates the curricular requisites possessed by the candidate and may request from the candidate a curricular supplement to be selected, due to the extent and nature of the required additions, from the following options:
 - A. Curricular additions to be made prior to enrollment, pursuant to art. 6 paragraph 1 of the Ministerial Decree March 16, 2007, by enrolling in individual courses activated at the University and passing the related exams, pursuant to art. 16 paragraph 6 of the University Didactic Regulations (see: <http://www.unina.it/-/5601348-registrati-ai-corsi-singoli>).

- B. Enrollment in a Degree Course which automatically enters the LM MOVE course with an abbreviation of the study course and an assignment of a Study Plan which provides for the curricular additions required for enrollment in the Master of Science Program.
- C. Enrollment in the Master's Degree course with assignment of a Study Plan which provides for alignment paths, in accordance with art. 6 paragraph 3 of the Ministerial Decree March 16, 2007, without additional credits.

Points of contact of LM MOVE

Prof. Antonio Moccia, Dipartimento di Ingegneria Industriale, email antonio.moccia@unina.it, Chairman of the LM MOVE Planning Committee

Prof. Rita Mastrullo, Direttore del Dipartimento di Ingegneria Industriale, email mastrullo@unina.it