UAB
Universitat Autònoma de Barcelona

Autonomous Navigation

Code: 106590
ECTS Credits: 6

2024/2025

Degree	Type	Year
2504392 Artificial Intelligence	OT	3
2504392 Artificial Intelligence	OT	4

Contact

Name: Antonio Manuel Lopez Peña
Email: antoniomanuel.lopez@uab.cat

Teaching groups languages

You can view this information at the end of this document.

Prerequisites

This subject follows a practical approach. However, it is based on the theoretical foundations taught in previous subjects of UAB's Artificial Intelligence Degree. Some of them are essential and the subjects in which they are taught should be considered a prerequisite for Autonomous Navigation: (1) Fundamentals of Mathematics II; (2) Data Engineering; (3) Neural Networks and Deep Learning; (4) Machine Learning Paradigms; (5) Vision and Learning.

Objectives and Contextualisation

Autonomous navigation refers here to the scientific and technical knowledge associated with the intelligent movement of physical systems. This broad definition encompasses a variety of systems, including small objects moving through the bloodstream to monitor and ensure health, household or industrial robots aiding in tasks requiring mobility, unmanned aerial vehicles monitoring forest areas to prevent fires or perform rescues, unmanned underwater robots exploring the seafloor, autonomous vehicles for delivering goods, and robotaxis or autonomous buses for urban transportation. Each of these systems presents its own unique characteristics and primary challenges. In fact, to capture the main commonalities and differences between multiple systems with autonomous navigation capabilities, we could propose several separate subjects such as body nanobots, underwater autonomous navigation, air autonomous navigation, unstructured land autonomous navigation, and structured land autonomous navigation.

Certainly, all of this knowledge cannot be covered by a single 6-ECTS university subject. Therefore, it is not surprising that, when it was planned as part of the UAB's AI degree, the focus was on autonomous driving technology for vehicles such as cars, trucks, or buses that must transport people and goods in structured land environments. Still, autonomous driving is based on multi-disciplinary knowledge, thus, we have to emphasize certain contents over others depending on the context of the subject. For instance, in the context of a degree in Telecommunications Engineering, Vehicle-to-X cooperative driving would be especially relevant; in the context of a degree in Automation and Industrial Systems Engineering the topics of local planning and control within a classical autonomous driving stack would be core knowledge; in the context of a degree in Physics, the sensors enabling autonomous driving may deserve especial interest. The subject that brings us together is within the UAB's degree in AI. Therefore, we willfocus on scientific and technical knowledge at the intersection of AI and autonomous driving. As a matter of fact, this field is still broad and continuously evolving, and there will be many topics not covered. We prefer to focus on fewer topics in more depth rather than covering more topics superficially.

On the one hand, we aim to cover a traditional SW stack for autonomous driving consisting of modules for perception, local planning, and control. But discarding the use of HD 3D maps, and so discarding VSLAM-based navigation. Moreover, Our focus will be on cameras among the various sensors used in this type of SW stack. Therefore, vision-based perception powered by deep learning will be the main connection between AI and autonomous driving within this modular SW stack paradigm. On the other hand, since the modular paradigm arises from the divide-and-conquer approach of classical engineering, we aim to cover a purer AI paradigm. In particular, we will cover visuomotor deep models for autonomous driving. Finally, hybrid approaches based on these two paradigms will be covered too.

The teaching methodology will follow a project-based approach. We will review the basic theoretical concepts so that students can grasp the overall picture and delve into the specific aspects needed to solve a project on autonomous driving. The specific project to be solved will depend on the particular computational resources and budget for materials that are assigned to our subject (these do not depend on the teachers and may change every year). However, in general terms, we aim to follow the usual approach we can find in the real world, which involves simulation and real-world developments.

Overall, the objective of this subject is to expose the students, through theory but mainly practice, to relevant core contents of autonomous driving, so that in the future they are ready to tackle new challenges in autonomous navigation. Last but not least, it is crucial to learn how to collaborate in a team to reach project success effectively.

Competences

Artificial Intelligence

- Analyse and solve problems effectively, generating innovative and creative proposals to achieve objectives.
- Conceive, design, analyse and implement autonomous cyber-physical agents and systems capable of interacting with other agents and/or people in open environments, taking into account collective demands and needs.
- Conceptualize and model alternatives of complex solutions to problems of application of artificial intelligence in different fields and create prototypes that demonstrate the validity of the proposed system.
- Identify, analyse and evaluate the ethical and social impact, the human and cultural context, and the legal implications of the development of artificial intelligence and data manipulation applications in different fields.
- Work cooperatively to achieve common objectives, assuming own responsibility and respecting the role of the different members of the team.

Learning Outcomes

1. Analyse and solve problems effectively, generating innovative and creative proposals to achieve objectives.
2. Design, simulate and evaluate autonomous driving systems.
3. Identify the best solutions for designing autonomous driving systems.
4. Identify the ethical and social impact and legal implications on the development of automated driving systems.
5. Work cooperatively to achieve common objectives, assuming own responsibility and respecting the role of the different members of the team.

Content

We will focus on three paradigms for autonomous driving:

(1) The modular paradigm, which includes perception enabled by deep learning, local planning, and control.
(2) The end-to-end driving paradigm, which is based on sensorimotor deep models trained by imitation learning.
(3) A hybrid paradigm that draws from the modular and end-to-end approaches.

Orthogonally to these paradigms, we will cover the following topics:

(1) Sensors that enable autonomous driving.
(2) Simulation-based development.
(3) Cooperative driving based on V2X communications.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Theoretical classes	10	0.4	3, 4
Type: Supervised			
Practical classes	38	1.52	1, 2, 3, 5
Type: Autonomous			
Study the theoretical content	13	0.52	3, 4
Team project	82	3.28	1, 2, 3, 5

The subject's contents will be deployed as follows:

(1) Theoretical classes will be taught to review key concepts related to autonomous driving, with a special focus on AI. The theoretical part will also include reading scientific articles.
(2) In the practical classes, tools/frameworks related to autonomous driving will be taught. A learning-by-practicing approach will be followed.
(3) A team project will be carried out to train a vehicle to perform autonomous driving maneuvers. Depending on available resources, the work will be carried out in a simulator and/or using a scale car.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Pair Evaluation (PE)	0.15	1	0.04	5

Practice Assessment (PrA)	0.2	2	0.08	1, 2, 3, 5
Project Assesment (PjA)	0.35	2	0.08	1, 2, 3, 5
Theory Assessment (TA)	0.3	2	0.08	3, 4

Single assessments are not considered.

The evaluation is continuous and will be based on the following marks:

Theory Assessment (TA): This is an individual assessment based on an exam to evaluate the theoretical knowledge acquired by the students.
Practice Assessment (PrA): Concerning the practices proposed by the lecturers, this is a team assessment based on the released code and documentation.
Project Assessment (PjA): Concerning the single project on autonomous driving proposed by the lecturers, this is a team assessment based on the obtained results, released code, and documentation.
Pair Evaluation (PE): A blind pair evaluation will be conducted to determine the level of active involvement of each student in the project developed by their team.

To pass the subject, all these sections must be passed separately. In other words, TA>=5, PrA>=5, PjA>=5, and PE>=5, where TA, PrA, PjA, and PE are grades out of 10. If this is true, then the final grade, FG, is calculated as:

FG = 0.3 TA + 0.2 PrA + 0.35 PjA + 0.15 PE.

NOTE: In cases where a student consistently fails to complete their work or makes only a minimal contribution (PE<5), the student will suspend the subject.
NOTE: PjA and PE are non-recoverable grades. If PjA<5, then no team member will pass the subject.
NOTE: TA and PrA are recoverable grades if (they are lower than 5) and (0.35 PjA + 0.15 PE>=3.5) and (PE>=5).

If a student fails to pass the subject, then their final garde (FG) will be min(TA,PrA,PjA,PE). It is understood that "Non-Evaluable" students are only those who have not undergone any evaluation/assessment activity.

MF grades (with Honors) will be given according to the UAB rules and considering features such as FG, continued work, relevance within the team, etc.

It should also be noted that students repeating the subject will not receive any special treatment, they must follow the subject as the rest of the students.

Without prejudice to other disciplinary measures deemed appropriate, and following current academic regulations, will be scored with a zero for the irregularities committed by the student that may lead to a variation of the qualification of an evaluation activity. Therefore, plagiarizing, copying, or allowing an assessment to be copied or any other evaluation activity, will involve suspending the activity with a zero so that it cannot be recovered in the same academic year. If this activity has a minimum associated score, then the subject will be suspended.

Bibliography

Autonomous driving is a constantly developing field. As a result, the most relevant literature changes continuously and is mainly available in the form of scientific articles. Therefore, instead of proposing a finalist bibliography when writing this guide, that is, seven months before the start of the subject, we will provide the most relevant literature at the start of the subject. On the other hand, if any student wants to read some materials beforehand, we suggest:

"A Survey of Autonomous Driving: Common Practices and Emerging Technologies" Ekim Yurtsever, Jacob Lambert, Alexander Carballo, Kazuya Takeda.
"A Survey of End-to-End Driving: Architectures and Training Methods", Ardi Tampuu, Maksym Semikin, Naveed Muhammad, Dmytro Fishman, Tambet Matiisen.
"End-to-end Autonomous Driving: Challenges and Frontiers", Li Chen, Penghao Wu, Kashyap Chitta, Bernhard Jaeger, Andreas Geiger and Hongyang Li.

All these articles can be found in arxiv.org, so there is a publicly available version of them.

Software

The software's requirements will vary depending on the specific practice and project. However, we anticipate a non-exclusive set of "keywords":

The CARLA simulator (carla.org)
The Robotic Operating System (ROS) 2 (https://docs.ros.org/en/foxy/index.html)
SCENIC (https://docs.scenic-lang.org/en/latest/)
Pytorch (https://pytorch.org/)

Language list

Name	Group	Language	Semester	Turn
(PAUL) Classroom practices	1	English	second semester	morning-mixed
(TE) Theory	1	English	second semester	morning-mixed