



الجمهورية الجزائرية الديمقراطية الشعبية
République Algérienne
Démocratique et Populaire
وزارة التعليم العالي والبحث العلمي
Ministère de l'Enseignement
Supérieur
et de la Recherche Scientifique

Ecole Nationale
Supérieure de
Technologie des
Systèmes
Autonomes



STATE ENGINEER TRAINING PROGRAM

Academic year: 2025/2026

Institution
National Higher School of Autonomous Systems Technology

Domain	Field	Specialty
<i>Science and Technology</i>	<i>Automatique</i>	<i>Unmanned Systems Navigation and Control</i>



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اللجنة البيداغوجية الوطنية
لميدان العلوم و التكنولوجيا
Comité Pédagogique
National du Domaine
Sciences et Technologies



عرض تكوين مهندس دولة

السنة الجامعية: 2025/2026

المؤسسة

المدرسة الوطنية العليا لتكنولوجيا الأنظمة المستقلة

الميدان	الفرع	التخصص
علوم وتكنولوجيا	الاية	الملاحة والتحكم في الأنظمة غير المأهولة

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Copy of order no. 062 of 22 January 2024

الجمهورية الجزائرية الديمقراطية الشعبية وزارة التعليم العالي والبحث العلمي

22 جان 2024

قرار رقم 062 المؤرخ في
يحدد البرنامج البيداغوجي للتكوين القاعدي
لثبيل شهادة مهندس دولة
بالمدرسة الوطنية العليا لتكنولوجيا الأنظمة المستقلة

إن وزير التعليم العالي والبحث العلمي،

- بمقتضى القانون رقم 99-05 المؤرخ في 18 ذي الحجة عام 1419 الموافق 4 أبريل سنة 1999 والمتضمن القانون التوجيهي للتعليم العالي، المعلن والمؤتمن،
- وبمقتضى المرسوم الرئاسي رقم 23-119 المؤرخ في 23 شعبان عام 1444 الموافق 16 مارس سنة 2023 والمتضمن تعيين أعضاء الحكومة، المعلن،
- وبمقتضى المرسوم التنفيذي رقم 13-77 المؤرخ في 18 ربيع الأول عام 1434 الموافق 30 يناير سنة 2013 الذي يحدد صلاحيات وزير التعليم العالي والبحث العلمي،
- وبمقتضى المرسوم التنفيذي رقم 16-176 المؤرخ في 9 رمضان عام 1437 الموافق 14 يونيو سنة 2016 الذي يحدد القانون الأساسي التوجيهي للمدرسة العليا،
- وبمقتضى المرسوم التنفيذي رقم 22-208 المؤرخ في 5 ذي القعدة عام 1443 الموافق 5 يونيو سنة 2022 الذي يحدد نظام التراسات والتكوين للحصول على شهادات التعليم العالي،
- وبمقتضى المرسوم التنفيذي رقم 23-434 مؤرخ في 18 جمادى الأولى عام 1445 الموافق 2 ديسمبر 2023 يتضمن إنشاء مدرسة وطنية عليا لتكنولوجيا الأنظمة المستقلة،
- وبمقتضى القرار رقم 1564 المؤرخ في 05 أكتوبر سنة 2016 والمتضمن إنشاء اللجنة البيداغوجية الوطنية للمدارس العليا حسب البلدان ويحدد صلاحياتها وتشكيلها وتنظيمها وسيرها،

يقرر:

- المادة الأولى: يحدد البرنامج البيداغوجي للتكوين القاعدي لثبيل شهادة مهندس دولة بالمدرسة الوطنية العليا لتكنولوجيا الأنظمة المستقلة، طبقا لملاحق هذا القرار.
- المادة 2: تطبق أحكام هذا القرار على دفعات الطلبة المسجلين بالمدرسة الوطنية العليا لتكنولوجيا الأنظمة المستقلة، ابتداء من السنة الجامعية 2023-2024.
- المادة 3: يكلف كل من السيد المدير العام للتعليم والتكوين ومدير المدرسة الوطنية العليا لتكنولوجيا الأنظمة المستقلة، كل فيما يخصه، بتطبيق هذا القرار الذي ينشر في النشرة الرسمية للتعليم العالي والبحث العلمي.

22 جان 2024

حرر بالجزائر في :

الوزير التعليم العالي والبحث العلمي

عبد الحكيم بن بلعيد



I. Training Context and Objectives

1- Background and Strategic Vision of the Training program

The National Higher School of Autonomous Systems Technology offers a three-year engineering program in Unmanned Systems Navigation and Control for students who have completed their preparatory cycle. This initiative aligns with the institution's mission to develop modern, rigorous engineering programs that respond to current technological needs.

The curriculum was designed in collaboration with academic and industrial partners to ensure both theoretical relevance and practical application. It integrates fundamental electronics principles with specialized knowledge in autonomous systems creating a comprehensive educational framework that prepares graduates for diverse professional paths.

This program is part of a coherent academic structure that includes complementary specializations in autonomous systems technologies:

- Unmanned Systems Navigation and Control (present program)
- Autonomous Embedded Systems Engineering
- Robotics and Autonomous Systems Design

The educational approach emphasizes balanced development of theoretical understanding and practical skills through laboratory work, project-based learning, and industrial internships. The program directly supports Algeria's strategic objectives for technological advancement and economic diversification while maintaining alignment with international standards.

2- Admission Requirements

Candidates for this engineering program are students from the National Higher School of Autonomous Systems Technology who have completed their preparatory cycle. Selection is based on merit ranking according to the overall average of the two preparatory years, subject to available places. Admission to the Autonomous Embedded Systems specialty follows the institution's internal progression protocols.

3- Program Objectives

The **Unmanned Systems Navigation and Control (USNC)** specialty is designed to equip engineers with comprehensive expertise in designing, developing, and operating unmanned systems across diverse environments, including terrestrial, aerial, and marine domains. The primary objective of this field is to ensure engineers are proficient in the intricate principles of navigation, control, and security of uncrewed vehicles. This encompasses mastering technologies like GPS, sensors, machine learning, and real-time decision-making systems to enable autonomy and adaptability in unmanned operations.

USNC professionals are trained to tackle complex challenges such as autonomous maritime drones, aerial drones for agriculture, and swarm robotics for coordinated tasks. This specialization emphasizes the integration of cutting-edge technologies; ensuring unmanned systems can operate safely and effectively in dynamic, real-world conditions. Graduates will be prepared to contribute to diverse sectors such as agriculture, defense, search-and-rescue missions, and environmental monitoring, pushing the boundaries of autonomous operations and technological innovation.

4- Targeted skills and Profiles

The **Unmanned Systems Navigation and Control (USNC)** specialty is aimed at developing highly skilled engineers who possess a diverse set of competencies required to excel in the rapidly evolving field of unmanned systems. The targeted profiles of graduates in this specialty include experts capable of designing, programming, and deploying autonomous systems in a variety of environments, such as terrestrial, aerial, and marine.

Targeted Profiles:

1. **Autonomous System Designer:** These professionals are adept at conceptualizing and developing unmanned systems with integrated navigation and control capabilities. They possess the technical know-how to create robust systems that can operate in dynamic and challenging environments.
2. **Robotics Engineer:** Skilled in the application of robotics principles, these engineers specialize in the development and deployment of swarm robotics, ensuring seamless cooperation among multiple unmanned systems to complete complex tasks autonomously.
3. **Aerial and Maritime Drone Specialist:** With a focus on specific types of unmanned systems, these engineers are proficient in the operation and

management of drones designed for agricultural, environmental, or defense applications, mastering both aerial and underwater vehicle technologies.

4. **Control Systems Engineer:** These engineers are experts in the design of control algorithms that ensure accurate and stable behavior of unmanned systems, even in unpredictable conditions.
5. **Security Expert in Unmanned Systems:** Engineers with a focus on the cybersecurity of unmanned systems, ensuring the safety of data, communications, and operations, as well as safeguarding against potential threats in autonomous operations.

Key Skills:

- **Advanced Navigation Techniques:** Proficiency in GPS, inertial navigation systems (INS), and other navigation methods, ensuring unmanned systems can operate autonomously in real-world conditions.
- **Control Systems and Algorithms:** Expertise in developing control systems, including the application of PID controllers, state estimation, path planning, and real-time decision-making algorithms.
- **Artificial Intelligence and Machine Learning:** Utilizing AI and ML to enhance the autonomy and adaptability of unmanned systems, enabling them to learn from their environment and optimize their operations.
- **Robotic Systems Integration:** Ability to integrate various components such as sensors, actuators, and communication systems to create effective unmanned vehicles.
- **Cybersecurity for Unmanned Systems:** Knowledge in securing communications, data transmission, and ensuring the safety of unmanned operations from cyber threats.
- **Communication Systems:** Understanding of communication protocols (e.g., GSM, RF, and satellite) to enable reliable interaction between unmanned systems and control stations.

Graduates of this specialty will be equipped with the interdisciplinary knowledge and hands-on experience necessary to innovate and advance unmanned systems technologies, driving the future of autonomous vehicles across various industries.

5- Regional and national employability potential

In Algeria, the Unmanned Systems Navigation and Control (USNC) specialty offers significant regional and national employability potential, as the demand for autonomous systems is growing across various sectors. The country's expanding interest in modern technologies, such as agriculture, defense, environmental monitoring, and oil and gas exploration, presents numerous opportunities for professionals skilled in unmanned systems. Agricultural drones, for example, are increasingly being used to monitor crops, while unmanned aerial vehicles (UAVs) are being adopted for surveillance and security purposes by defense and civil agencies. Additionally, Algeria's strategic location and its investments in maritime and aerospace sectors open up career pathways in both government agencies and private companies. As the country continues to modernize its infrastructure and technological capabilities, the demand for skilled engineers in the field of unmanned systems will only increase, making USNC graduates highly sought after in the local job market.

6- Bridges to other specialties

The Unmanned Systems Navigation and Control Engineer specialty offers strong connectivity with related disciplines, facilitating academic mobility and career development. Students may request transfers to other electrical engineering specializations within Algerian universities.

Our program's comprehensive curriculum creates multiple pathways for graduates. Those wishing to pursue academic careers can seamlessly transition into research teams across various domains, including robotics, artificial intelligence, IoT systems, and control engineering. The foundational knowledge and specialized skills acquired throughout this program prepare students for industry leadership and scholarly advancement in emerging technological fields in Algeria and beyond.

The interdisciplinary nature of Unmanned Systems Navigation and Control naturally creates bridges to specializations in telecommunications, control systems, computer engineering, and power electronics, allowing graduates to pivot their careers according to technological evolution and personal interests.

7- Program monitoring indicators

The Unmanned Systems Navigation and Control Engineering program employs a comprehensive set of key performance indicators to ensure continuous quality improvement and alignment with industry needs. These metrics enable systematic

monitoring of educational outcomes and program effectiveness across multiple dimensions:

Academic Performance Metrics:

- Application rates and selectivity ratios for incoming cohorts
- Program completion rates and graduation statistics
- Average time to graduation and credit accumulation patterns
- Academic performance distribution across core and specialized Lectures

Professional Integration Assessment:

- Employment rate of graduates within six months and one year of program completion
- Sectorial distribution of graduate employment across industries
- Percentage of graduates securing positions in their field of specialization
- Career progression trajectories of Alumni over three and five-year periods

Research and Academic Advancement:

- Number of graduates pursuing doctoral studies
- Research publications stemming from capstone projects
- Participation rates in academic conferences and technical competitions
- Intellectual property development from student projects

Stakeholder Feedback Mechanisms:

- Structured evaluations from current students at mid-program and completion stages
- Alumni satisfaction surveys conducted at one and three years post-graduation
- Employer assessments of graduate preparedness and performance
- Industry partner feedback on curriculum relevance and emerging skill requirements

Partnership Development Indicators:

- Growth in industry partnerships for internships and capstone projects
- Expansion of research collaborations with national and international institutions
- Development of exchange opportunities with partner schools
- Engagement levels with the Algerian innovation ecosystem

The program administration conducts annual reviews of these indicators, enabling data-driven refinement of curriculum content, teaching methodologies, and industry alignment to ensure graduates remain at the forefront of autonomous systems engineering practice in Algeria and beyond.

8 – Human resources available

A : Enrollment Capacity

150 students (50 per promotion)

B : Academic Supervision Team

B-1 : Internal Supervision

Name	Speciality	Rank	Intervention Type
Mourad ADNANE	Instrumentation/ Signal Processing	Prof	Course/Tutorials/Lab
Kamel BOUDJIT	Electronics/Embedded Systems	MCA	Course/Tutorials/Lab
Tarek CHERIFI	Electronics/Embedded Systems	MCA	Course/Tutorials/Lab
Leila ABBAD	Electronics/ Networks	MCB	Course/Tutorials/Lab
Ahmed ZEGLAOUI	Mathematics/ Optimization	MCB	Course/Tutorials/Lab
Yasmine GUERBAI	Electronics/AI	MCA	Course/Tutorials/Lab
Salaheddine AOUDJ	Chemistry/Electrochemistry	MCA	Course/Tutorials/Lab
Faiza BOUMEDIENE	Mechanics/Robotics	Pr	Course/Tutorials/Lab
Halima LAMMARI	Mechanics/Robotics	MCB	Course/Tutorials/Lab
Abdelkader HAMTTAT	Mathematics	MCA	Course/Tutorials/Lab
Mohamed LAIDI	Statistics	MCA	Course/Tutorials/Lab
Said REZIG	Mathematics	MAA	Course/Tutorials/Lab

Ziane KECHIDI	Physics/	Prof	Course/Tutorials/Lab
Ouassila HIOUAL	Informatics/AI	Prof	Course/Tutorials/Lab

B-2 : External Supervision

Name	Speciality	Institution	Rank	Intervention Type
Mohamed TADJINE	Control Engineering/Robotics	ENP	Prof	Course/Tutorials/Lab
Fouad YACEF	Control Engineering/Drones	CDTA	Dr	Course/Tutorials/Lab
Rabie Riadh BENREZKI	Navigation and Control	CDTA	Dr	Course/Tutorials/Lab
Abdellah KHELLOUFI	Navigation and Control	CDTA	Dr	Course/Tutorials/Lab
Mohamed ZAUCHE	Control Engineering/USAS	Expert	Dr	Course/Tutorials/Lab

B-3 : Comprehensive Summary of Human Resources

Rank	Internal resource	External resource	Total
Professor	3	1	4
MCA	6	3	9
MCB	3	0	3

B-4 : Permanent Support Staff

Rank	Staff
Laboratory Engineer	1
Computer Engineer	1
Administrator	4
Administrative Assistant	2
Total	8

7 – Available Material Resources

A- Educational Facilities

Location	Seating Capacity	Number	Total Capacity
Lecture Hall	200	4	800
Tutorial Room	30	15	450
Practical Lab	25	15	375
Library	30	1	30
Reading Rooms	40	2	80
Workshop	10	1	10
Computing Center	40	1	40
Internet Room	40	2	80

B- Educational Laboratories and Equipment

Laboratory Name : Electricity Lab

Student Capacity: 25

N°	Equipement	Quantity	Operational Status
1	Amperemeter	13	Excellent state
2	Galvanometer	02	Excellent state
3	Voltmeter	12	Excellent state
4	Multimeter	05	Excellent state
5	Wattmeter	07	Excellent state
6	Power supply	10	Excellent state
7	Power supply module	06	Excellent state
8	Low-Frequency Generator	06	Excellent state
9	Oscilloscope	10	Excellent state
10	Breadboards	20	Excellent state

• **Laboratory Name:** Physics Lab 1

Student Capacity: 25

N°	Equipment	Quantity	Operational Status
1	Force tables	01	Excellent state
2	Free Fall	04	Excellent state
3	Simple Pendulum	05	Excellent state
4	Air track	03	Excellent state
5	PasCars	02	Excellent state
6	Torsion pendulum	02	Excellent state
7	Balance of Coulomb	05	Excellent state
8	electric field strengthmeter	05	Excellent state
9	Tank Rheographic	04	Excellent state
10	Analogic voltmeter	07	Excellent state
11	Analogic Ammeter	07	Excellent state

• **Laboratory Name: physics Lab 2**

Student Capacity: 25

N°	Equipment	Quantity	Operational Status
01	Pohl's Pendulum	1	Excellent state
02	Wave Tank/Ripple Tank	1	Excellent state
03	Vibrating String/Cord	1	Excellent state
04	Kundt's Tube	1	Excellent state
05	Light Polarization (Equipment)	1	Excellent state
06	Light Diffraction (Equipment)	1	Excellent state

• **Laboratory Name: Chemistry Laboratory.**

Student Capacity: 25

N°	Equipment	Quantity	Operational Status
01	Fume hood	01	Excellent state
02	Oven/Incubator	01	Excellent state
03	Distiller	01	Excellent state
04	Ice generator	01	Excellent state
05	Calorimeter	04	Excellent state
06	Heating plates	04	Excellent state
07	Heater with stirrer	01	Excellent state
08	Scale/Balance	02	Excellent state
09	pH meter	04	Excellent state
10	Dosing equipment with pH meter	02	Excellent state
11	Thermometer	15	Excellent state
12	Stopwatch/Timer	06	Excellent state
13	Power supplies for calorimetry	02	Excellent state
14	Voltmeter for calorimetry	02	Excellent state
15	Ammeter for calorimeter	02	Excellent state

• **Laboratory Title: Fluid Mechanics.**

Student Capacity: 25

N°	Equipment	Quantity	Operational Status
01	Digital Hydraulic Bench	01	Excellent state
02	Center of Pressure Apparatus	02	Excellent state
03	Falling Sphere Viscometers	02	Excellent state
04	Venturi Tube	01	Excellent state
05	Notch Discharge Apparatus	01	Excellent state

• **Laboratory Title: Mechanics Laboratory.**

Student Capacity: 25.

N°	Equipment	Quantity	Operational Status
01	Materials Testing Apparatus	01	Excellent state

C- Internship and Corporate Training Sites Training Sites

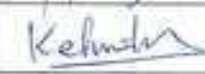
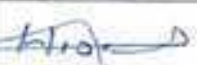
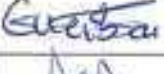
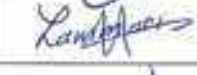
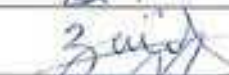
Institution	Student Number	Training Duration
Mobilis	20	15 days
CRTI	20	15 days
CDTA	20	15 days
DeepMinds	5	15 days
Sonatrach	20	15 days
SEAAL	10	15 days
SONELGAZ	10	15 days

D-Personal Workspaces and Information Technology Resources

The institution provides students with a well-equipped library featuring a spacious reading room designed for academic study. High-speed internet connectivity is available throughout all campus facilities, ensuring continuous access to digital resources.

signatures of teachers involved in the course

Internal teaching team for the specialty

Name	Speciality	Rank	Intervention Type	Signature
Mourad ADNANE	Instrumentation / Signal Processing	Prof	Course/Tutorials/Lab	
Faiza BOUMEDIENE	Mechanics / Robotics	Prof	Course/Tutorials/Lab	
Ziane KECHIDI	Physics	Prof	Course/Tutorials/Lab	
Ouassila HIOUAL	Computer Sciences	Prof	Course/Tutorials/Lab	
Kamel BOUDJIT	Electronics / Embedded Systems	MCA	Course/Tutorials/Lab	
Salaheddine AOUDJ	Chemistry / Electrochemistry	MCA	Course/Tutorials/Lab	
Tarek CHERIFI	Electronics / Embedded Systems	MCA	Course/Tutorials/Lab	
Abdelkader HAMTTAT	Mathematics	MCA	Course/Tutorials/Lab	
El mahdi MEDIA	Physics	MCA	Course/Tutorials/Lab	
Yasmine GUERBAI	Electronics / Artificial Intelligence	MCA	Course/Tutorials/Lab	
SAIB Abdessadek	Mathematics	MCA	Course/Tutorials/Lab	
Leila ABBAD	Electronics / Networking	MCB	Course/Tutorials/Lab	
Sarah CHENCHE	Computer Sciences/Artificial Intelligence	MCB	Course/Tutorials/Lab	
Mohamed LAIDI	Statistics / Stochastic processes	MCB	Course/Tutorials/Lab	
Halima LAMMARI	Mechanics / Robotics	MCB	Course/Tutorials/Lab	
Ahmed ZEGLAOUI	Mathematics / Optimization	MCB	Course/Tutorials/Lab	
Snid REZIG	Mathematics	MAA	Course/Tutorials/Lab	
Fatiha KADIK	Mathematics	MAA	Course/Tutorials/Lab	
ZAIR Mustapha	Computer Sciences	MAA	Course/Tutorials/Lab	

School director's stamp

External teaching team for the specialty

Name	Specialty	Institution	Rank	Intervention Type	Signature
Moufid MANSOUR	Control Eng	USTHB	Prof	Course Responsible	
Mohamed TADJINE	Control Eng / Robotics	ENP	Prof	Course Responsible	
Abdelhalim ZAOUI	Electrical Eng	ENSTA	Prof	Course Responsible	
Malika BOUTERFAS	Electronics / Sensors	ENSTA	MCA	Course Responsible	
Tarek CHERIFI	Electronics / Embedded systems	ENSTA	MCA	Course Responsible	
Souhila BOUTARFA	- Electronics / Signal processing	ENSTA	MCB	Course Responsible	
Nesrine ISSAAD	Bioinformatics / Artificial intelligence	U. Algiers	MCB	Course Responsible	
kheira Lakhdari	Telecommunication / Artificial intelligence	ENSTA	MCB	Course Responsible	
Fouad YACEF	Control Eng / Drones	CDTA	Dr	Course Responsible	
Rabie Riadh BENREZKI	Navigation and Control	CDTA	Dr	Course Responsible	
Abdellah KHELLOUFI	Navigation and Control	CDTA	Dr	Course Responsible	
Mohamed ZAOUCHE	Control Eng / UAS	Expert	Dr	Course Responsible	
Abdelkader BELAHCENE	Computer Science / Open Source software	ENSTA	MAA	Course Responsible	

School director's stamp

Semester 5 :

Unité d'Enseignement UE	Volume horaire semestriel (15 semaines / semestre)					Coefficients	Credits
	Cours (h)	Travaux dirigés (h)	Travaux pratiques(h)	Travail Personnel (h)	Total (h)		
Unité d'Enseignement Fondamentale							
UEF1.1.1	4	3	2	2	11	8	8
Linear Control Systems	2	1.5	1	1	5.5	4	4
Embedded Systems Design	2	1.5	1	1	5.5	4	4
UEF1.1.2	6	4.5	3	3	16.5	12	12
Advanced Electronics	2	1.5	1	1	5.5	4	4
Instrumentation and Sensors	2	1.5	1	1	5.5	4	4
Digital Signal Processing	2	1.5	1	1	5.5	4	4
Unité d'Enseignement Méthodologie							
UEM1.1.1	3	1	3	2	9	6	6
Introduction to Linux	1	0	2	1	4	3	3
Optimization Techniques	2	1	1	1	5	3	3
Unité d'Enseignement Transversale							
UET1.1.1	1	0	0	1	2	2	2
Ethics and Safety in AI and Robotics	1	0	0	1	2	2	2
Unité d'Enseignement Découverte							
UED1.1.1	1.5	0	0	1	2.5	2	2
Principles of Flight and Aeronautics	1.5	0	0	1	2.5	2	2
Total Semestre S1	15.5	8.5	8	9	41	30	30

Semester 6 :

Unité d'Enseignement UE	Volume horaire semestriel (15 semaines / semestre)					Coefficients	Credits
	Cours (h)	Travaux dirigés (h)	Travaux pratiques(h)	Travail Personnel (h)	Total (h)		
Unité d'Enseignement Fondamentale							
UEF1.2.1	4	2.5	2	2	10.5	7	7
State Space Analysis and Control Design	2	1	1	1	5	4	4
Kinematics and Dynamics of Unmanned Systems	2	1.5	1	1	5.5	3	3
UEF1.2.2	4	3	2	2	11	6	6
Modeling and Control of Robotic Manipulators	2	1.5	1	1	5.5	3	3
Actuators	2	1.5	1	1	5.5	3	3
Unité d'Enseignement Méthodologie							
UEM1.2.1	2	1	3	2	8	6	6
Communication Systems	1	1	1	1	4	3	3
Real Time Operating Systems	1	0	2	1	4	3	3
UEM1.2.2	2.5	1	3	2	8.5	6	6
Power Electronics	1.5	1	1	1	4.5	3	3
Introduction to Machine Learning	1	0	2	1	4	3	3
Unité d'Enseignement Transversale							
UET1.2.1	1	0	0	1	2	2	2
Regulations and Standards for Unmanned Systems	1	0	0	1	2	2	2
Unité d'Enseignement Découverte							
UED1.2.1	0	0	1	3	4	3	3
Capstone Project I	0	0	1	1	2	2	2
Training Internship I	/	/	/	2	2	1	1
Total Semestre S2	13.5	7.5	11	12	44	30	30

Semester 7:

Unité d'Enseignement UE	Volume horaire semestriel (15 semaines / semestre)					Coefficients	Credits
	Cours (h)	Travaux dirigés (h)	Travaux pratiques(h)	Travail Personnel (h)	Total (h)		
Unité d'Enseignement Fondamentale							
UEF2.1.1	5	2	3.5	3	13.5	9	9
Multivariable Control Systems Design	2	1	1	1	5	3	3
Computer Vision	2	0	1.5	1	4.5	3	3
System Identification	1	1	1	1	4	3	3
UEF2.1.2	5.5	2	3.5	3	14	9	9
Fundamentals of Autonomous Navigation	2	1	1	1	5	3	3
Filtering and Recursive Estimation	2	1	1	1	5	3	3
Advanced Embedded Systems Design	1.5	0	1.5	1	4	3	3
Unité d'Enseignement Méthodologie							
UEM2.1.1	1	0	2	1	4	3	3
Neural Networks and Deep Learning	1	0	2	1	4	3	3
Unité d'Enseignement Transversale							
UET2.1.1	1.5	1	3	2	7.5	5	5
Antennas and Propagation	1.5	1	1	1	4.5	3	3
Mechanical CAD for Robotics	0	0	2	1	3	2	2
Unité d'Enseignement Découverte							
UED2.1.1	1	0	1	2	4	4	4
Project Management for Engineers	1	0	0	1	2	2	2
Capstone Project II	0	0	1	1	2	2	2
Total Semestre S3	14	5	13	11	43	30	30

Semester 8:

Unité d'Enseignement UE	Volume horaire semestriel (15 semaines / semestre)					Coefficients	Credits
	Cours (h)	Travaux dirigés (h)	Travaux pratiques(h)	Travail Personnel (h)	Total (h)		
Unité d'Enseignement Fondamentale							
UEF2.2.1	4	2	2	2	10	6	6
Non Linear Control Systems	2	1	1	1	5	3	3
Optimal Control	2	1	1	1	5	3	3
UEF2.2.2	5.5	2.5	4	3	15	9	9
Advanced AI Techniques	1.5	0	2	1	4.5	3	3
Advanced Navigation Systems	2	1.5	1	1	5.5	3	3
Aerodynamics and Hydrodynamics	2	1	1	1	5	3	3
Unité d'Enseignement Méthodologie							
UEM2.2.1	4	1	3	3	11	9	9
Human-robot Interaction	1	1	1	1	4	3	3
UAV Flight Testing and Operations	0	0	2	1	3	3	3
Propulsion Systems	3	0	0	1	4	3	3
Unité d'Enseignement Transversale							
UET2.2.1	1	0	1	1	3	3	3
Cybersecurity for Unmanned Systems	1	0	1	1	3	3	3
Unité d'Enseignement Découverte							
UED2.2.1	1.5	0	2	5	8.5	3	3
Reverse Engineering and Rapid Prototyping	1.5	0	0	1	2.5	1	1
Capstone Project III	0	0	2	2	4	1	1
Training Internship II	/	/	/	2	2	1	1
Total Semestre S4	16	5.5	12	14	47.5	30	30

Semester 9:

Unité d'Enseignement UE	Volume horaire semestriel (15 semaines / semestre)					Coefficients	Credits
	Cours (h)	Travaux dirigés (h)	Travaux pratiques(h)	Travail Personnel (h)	Total (h)		
Unité d'Enseignement Fondamentale							
UEF3.1.1	4	1	2	2	9	8	8
Advanced UAS Programming	1	1	2	1	5	4	4
Fundamentals of Aerospace Engineering	3	0	0	1	4	4	4
UEF3.1.2	3.5	3	2.5	2	11	6	6
Electric Vehicles and Energy Systems	2	1.5	1	1	5.5	3	3
Reinforcement Learning	1.5	1.5	1.5	1	5.5	3	3
Unité d'Enseignement Méthodologie							
UEM3.1.1	4	1	1	2	8	6	6
Swarm Robotics and Multi-Agent Systems	1	1	1	1	4	3	3
Unmanned Systems Practical Cases	3	0	0	1	4	3	3
Unité d'Enseignement Transversale							
UET3.1.1	2	0	2	2	6	6	6
Biomimétisme and Bio-inspired Robotics	1	0	1	1	3	3	3
Industrial Automation	1	0	1	1	3	3	3
Unité d'Enseignement Découverte							
UED3.1.1	2	0	4	5	11	4	4
Training Internship III	0	0	0	2	2	1	1
Capstone Project IV	1	0	4	2	7	2	2
Academic Communication and Research	1	0	0	1	2	1	1
Total Semestre S5	15.5	5	11.5	13	45	30	30

Semester 10:

Students complete internships in companies or research laboratories, which conclude with the submission of a thesis and an oral defense.

Internship and Final Year Project	Semester Hourly Volume	Coefficients
14 Weeks	420 hours	30
Total	420 hours	30

III - Detailed Syllabus by Subject

Course List

Semester 5

Matière: Linear Control Systems **Code:** LCS
Matière: Embedded Systems Design **Code:** ESD
Matière: Advanced Electronics **Code:** ADE
Matière: Instrumentation and Sensors **Code:** INS
Matière: Digital Signal Processing **Code:** DSP
Matière: Introduction to Linux **Code:** ILI
Matière: Optimization Techniques **Code:** OPT
Matière: Ethics and Safety in AI and Robotics **Code:** ESAIR
Matière: Principles of Flight and Aeronautics **Code:** PFA

Semester 6

Matière: State Space Analysis and Control Design **Code:** SSACD
Matière: Kinematics and Dynamics of Unmanned Systems **Code:** KDUS
Matière: Modeling and Control of Robotic Manipulators **Code:** MCRM
Matière: Actuators **Code:** ACT
Matière: Communication Systems **Code:** CSY
Matière: Real Time Operating Systems **Code:** RTOS
Matière: Power Electronics **Code:** POE
Matière: Introduction to Machine Learning **Code:** IML
Matière: Regulations and Standards for Unmanned Systems **Code:** RSUS
Matière: Capstone Project I **Code:** CP-I
Matière: Training Internship I **Code:** TI-I

Semester 7

Matière: Multivariable Control Systems Design **Code:** MCSD
Matière: Computer Vision **Code:** CV
Matière: System Identification **Code:** PID
Matière: Fundamentals of Autonomous Navigation **Code:** FAN
Matière: Filtering and Recursive Estimation **Code:** FRE
Matière: Advanced Embedded Systems Design **Code:** AESD
Matière: Neural networks and Deep Learning **Code:** NNDL
Matière: Antennas and Propagation **Code:** APR
Matière: Mechanical CAD for Robotics **Code:** MCR
Matière: Project Management for Engineers **Code:** PME
Matière: Capstone Project II **Code:** CP_II

Semester 8

Matière: Nonlinear Control Systems **Code:** NCS
Matière: Optimal Control **Code:** OC
Matière: Advanced AI techniques **Code:** AAT
Matière: Advanced Navigation Systems **Code:** ANS
Matière: Aerodynamics and Hydrodynamics **Code:** AH
Matière: Human-robot interaction **Code:** HRI
Matière: UAV Flight Testing and Operations **Code:** UFTO

Matière: Cybersecurity for Unmanned Systems **Code:** CUS
Matière: Reverse Engineering and Rapid Prototyping **Code:** REPP
Matière: Capstone Project III **Code:** CP-III
Matière: Training Internship II **Code:** TI_II

Semester 9

Matière: Advanced UAS Programming **Code:** AUP
Matière: Fundamentals of Aerospace Engineering **Code:** FAE
Matière: Electric Vehicles and Energy Systems **Code:** EVES
Matière: Reinforcement Learning **Code:** REL
Matière: Swarm Robotics and Multi-Agent Systems **Code:** SRMAS
Matière: Unmanned Systems Practical Cases **Code:** USPC
Matière: Humanoid and Bio-inspired Robotics **Code:** HBIR
Matière: Industrial Automation **Code:** INA
Matière: Training Internship III **Code:** TI-III
Matière: Capstone Project IV **Code:** CP-IV
Matière: Academic Communication and Research **Code:** ACR

Detailed programs for the fifth semester

Teaching Unit	Subject Title	Code	Semester
UEF1.1.1	Linear Control Systems	LCS	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	4/4

I. Course Objectives:

By the end of this course, students will:

- Understand the principles of continuous and discrete time control systems.
- Model dynamic systems using differential equations and difference equation.
- Analyze system stability and performance in time and frequency domains.
- Design and tune PID controllers.

II. Targeted Skills:

Upon completing this course, students will have developed the following skills:

Technical Skills:

- Modeling and analyzing dynamic systems.
- Designing and tuning control systems.

Analytical Skills:

- Solving control problems using mathematical tools.
- Evaluating system performance and stability.

Practical Skills:

- Using softwares for simulation and analysis.

III. Recommended prerequisites:

To succeed in this course, students should have:

- Basic knowledge of calculus and linear algebra.
- Familiarity with differential equations.
- Introductory knowledge of physics and dynamics.

IV. Content / Content:

This course introduces the fundamental principles of continuous-time control systems. Students will learn to model, analyze, and design control systems for dynamic systems.

Topics:

Chapter 1: Introduction to Control Systems

- Definition and applications of control systems.
- Examples of control systems in engineering.

Chapter 2: Mathematical Modeling of Dynamic Systems

- Differential equations, Laplace Transform, and transfer functions.

- Mechanical, electrical, and electromechanical systems.
- Difference equations, Z Transform, digital Systems

Chapter 3: Time-Domain Analysis

- Transient and steady-state response.
- First-order and second-order systems.
- Performance metrics: rise time, settling time, overshoot, and steady-state error.

Chapter 4: Stability Analysis

- Routh-Hurwitz criterion.
- Root locus method.

Chapter 5: Frequency-Domain Analysis

- Bode plots and Nyquist plots.
- Gain and phase margins.

Chapter 6: Continuous time Controller Design.

- P and PI controllers.
- PID controller .
- Filtered PID controller

Chapter 7: Discrete time Controller Design

- Digital P and PI controller.
- Digital PID controller .

Lab Work

Lab 1: Time domain analysis of 1st and 2nd order Systems

Lab 2: Frequency domain analysis of 1st and 2nd order Systems

Lab 3: Continuous and Digital PID tuning

Lab 4: Speed Control of DC motor.

Lab 5: Position control of DC motor.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Katsuhiko Ogata – Modern Control Engineering (5th Edition, 2010)
2. Norman S. Nise – Control Systems Engineering (7th Edition, 2015)
3. Richard C. Dorf & Robert H. Bishop – Modern Control Systems (13th Edition, 2016)
4. Benjamin C. Kuo & Farid Golnaraghi – Automatic Control Systems (9th Edition, 2014)
5. Graham C. Goodwin, Stefan F. Graebe, & Mario E. Salgado – Control System Design (1st Edition, 2001)

Teaching Unit	Subject Title	Code	Semester
UEF1.1.1	Embedded Systems Design	ESD	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	4/4

I. Course Objectives

- To introduce the fundamental concepts of embedded systems and their applications.
- To explore microcontroller and microprocessor architectures, including Von Neumann and Harvard architectures.
- Introduces microcontroller programming, focusing on understanding the architecture and programming techniques of microcontrollers.
- Students will learn how to program microcontrollers using the assembly and the C programming languages, interface peripherals, and develop embedded systems applications.
- To learn the basics of hardware interfacing and communication protocols.
- To gain practical experience in designing and implementing embedded control systems.

II. Targeted Skills

- Understanding microcontroller and microprocessor architectures.
- Interfacing sensors and actuators with embedded systems.
- Programming embedded systems for real-time applications.
- Designing and debugging simple embedded control systems.

III. Recommended prerequisites

- Basic knowledge of digital electronics and computer architecture.
- Familiarity with C/C++ programming.

IV. Content

Chapter 1: Introduction to Embedded Systems

- Definition and applications of Embedded Systems.
- Basic components of embedded systems (microprocessor, microcontroller, DSP, SoC, NoC, FPGA, ASIC, SiP ...etc.).
- Microcontrollers vs. Microprocessors .
- Von Neumann and Harvard Architectures, CISC vs. RISC Architectures.

Chapter 2: Introduction to Microcontrollers

- Definition of microcontrollers.
- Architecture and components of a typical microcontroller.
- Types and characteristics of microcontrollers (8-bit, 16-bit, 32-bit, low power, high performance, wireless ...etc.).
- Programming abstraction levels (machine language, assembly, high-level programming languages).

Chapter 3: Study of a specific Microcontroller

- Overview of different microcontroller families available in the market, advantages and disadvantages of each.
- Introduction to the selected microcontroller family (e.g., AVR, PIC, ARM).
- Architectural overview, including CPU, types of Memory: (SRAM, EEPROM, Flash), memory organization, and peripherals.
- Addressing modes.
- Examination of the microcontroller's instruction set.
- Detail the execution of instructions, fetch cycles.
- Sleep modes.
- Microcontroller programming in assembly language.
- Microcontroller programming in high-level language (C, Python ...etc.).

Chapter 4: Interrupts and Timers

- Understanding interrupts and their importance in microcontroller programming.
- Interrupt vector tables, NVIC (if ARM-based)
- Writing ISRs (Interrupt Service Routines).
- Timer modules and their applications.

Chapter 5: Peripherals and Interfacing

- General-Purpose Input/Output (GPIO). Pull-up and pull-down resistors.
- Analog and Digital Interfacing: ADC and DAC.
- Pulse Width Modulation (PWM)
- Interfacing with LEDs, switches, and sensors.

Chapter 6: Communication Protocols

- UART (Universal Asynchronous Receiver-Transmitter).
- SPI (Serial Peripheral Interface).
- I2C (Inter-Integrated Circuit).
- CAN (controller area network).

Chapter 7: Design Practices and Debugging (1 week)

- Modular firmware architecture
- Drivers and HAL
- Debugging tools: logic analyzer, oscilloscope, GDB

Practical Lab: Building Embedded Control Systems

Lab1: Familiarization with a specific microcontroller (e.g., ATmega328P or STM32) and development tools. Write a simple C program to toggle an LED using GPIO. Button-controlled LED or Buzzer project.

Lab2: LED dimming using PWM and Interrupt-based button press counter.

Lab3: Sending sensor data over UART to a PC serial monitor.

Lab4: Display temperature readings using ADC and serial output.

Lab5: Design a simple complete system. Design Practices and use Debugging tools (e.g., smart fan, automatic light controller).

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Barr, M., & Massa, A. (2006). *Programming Embedded Systems: With C and GNU Development Tools*. O'Reilly Media.
2. David A. Patterson and John L. Hennessy. Computer Organization and Design: The Hardware/Software Interface.
3. Muhammad Ali Mazidi, Sarmad Naimi, and Sepehr Naimi. The AVR Microcontroller and Embedded Systems: Using Assembly and C.
4. Muhammad Ali Mazidi, Rolin D. McKinlay, and Danny Causey. PIC Microcontroller and Embedded Systems: Using Assembly and C for PIC 18.
5. Wolf, W. (2008). *Computers as Components: Principles of Embedded Computing System Design*. Elsevier.
6. Yiu, J. (2015). *The Definitive Guide to ARM Cortex-M Processors*. Newnes.
7. Labrosse, J. J. (2002). *MicroC/OS-II: The Real-Time Kernel*. CMP Books.
8. Burns, A., & Wellings, A. (2001). *Real-Time Systems and Programming Languages*. Addison-Wesley.

Teaching Unit	Subject Title	Code	Semester
UEF1.1.2	Advanced Electronics	ADE	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	4/4

I. Course Objectives

- To provide in-depth knowledge of electronic circuits used in signal amplification, signal generation, and signal modulation.
- To explore the principles of transistors and operational amplifiers in amplification applications.
- To study oscillators, Analog-to-Digital (ADC), and Digital-to-Analog (DAC) conversion techniques.
- To understand different modulation techniques such as AM, FM, and PM.
- To introduce Phase-Locked Loops (PLL) and their applications in modern communication systems.
- To develop the ability to analyze and design electronic circuits in communication and control systems.

II. Targeted Skills

- Design and analysis of amplification circuits using transistors and operational amplifiers.
- Understanding and designing oscillators, ADC, and DAC circuits.
- Mastery of amplitude, frequency, and phase modulation techniques.
- Implementation and application of Phase-Locked Loops (PLL) in real-world scenarios.
- Practical knowledge of modern electronic components used in communication and control systems.

III. Recommended prerequisites

- Basic circuit theory (Ohm's Law, Kirchhoff's Laws, Thevenin and Norton Theorems)
- Fundamental electronics (Diodes, BJTs, MOSFETs, and basic operational amplifier configurations)
- Fourier Transform and basic filtering techniques
- Introduction to digital logic and microcontrollers

IV. Content

Chapter 1: Amplification

1.1 Introduction to Amplification

- Definition and importance of amplification
- Types of amplifiers (voltage, current, and power amplifiers)

1.2 Transistor-Based Amplifiers

- Bipolar Junction Transistor (BJT) amplifiers
- Field Effect Transistor (FET) amplifiers

- Common-emitter, common-base, and common-collector configurations
- Frequency response and bandwidth considerations

1.3 Operational Amplifiers (Op-Amps)

- Ideal vs. real op-amps
- Inverting and non-inverting configurations
- Differential, summing, and instrumentation amplifiers
- Op-amp limitations and compensation techniques

Chapter 2: Oscillators, ADC, and DAC

2.1 Oscillators

- Principle of oscillation
- RC and LC oscillators
- Crystal oscillators
- Stability and frequency control

2.2 Analog-to-Digital Converters (ADC)

- Sampling theorem and quantization
- Successive approximation ADC
- Flash, Sigma-Delta, and pipeline ADCs
- Performance parameters (resolution, SNR, conversion time)

2.3 Digital-to-Analog Converters (DAC)

- R-2R ladder DAC
- Weighted resistor DAC
- Performance parameters (linearity, resolution, conversion rate)

Chapter 3: Modulation Techniques (AM, FM, PM)

3.1 Introduction to Modulation

- Need for modulation
- Comparison between analog and digital modulation

3.2 Amplitude Modulation (AM)

- Concept and mathematical representation
- Single Sideband (SSB) and Double Sideband (DSB) AM
- Envelope detection and demodulation

3.3 Frequency Modulation (FM)

- Mathematical representation
- Frequency deviation and bandwidth considerations
- FM generation and detection techniques

3.4 Phase Modulation (PM)

- Concept and mathematical representation
- Comparison with frequency modulation
- PM applications

Chapter 4: Phase-Locked Loop (PLL)

4.1 Introduction to PLL

- Basic principle of operation

- Applications in frequency synthesis and demodulation

4.2 PLL Components and Design

- Phase detector, voltage-controlled oscillator (VCO), and loop filter
- Lock range, capture range, and hold-in range
- Practical implementations and simulations

4.3 Applications of PLL

- Frequency synthesis
- Clock recovery in digital communication
- FM demodulation

Lab Work

Lab 1: Amplification à base de Transistors

Lab 2: Operational Amplifiers

Lab 3: Oscillators

Lab 4: Analog Modulations

Lab 5: Phase Locked Loop

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
 - The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Sedra, A. S., & Smith, K. C. (2018). Microelectronic Circuits. Oxford University Press.
2. Razavi, B. (2015). Fundamentals of Microelectronics. Wiley.
3. Floyd, T. L. (2020). Electronic Devices (Conventional Current Version). Pearson.
4. Horowitz, P., & Hill, W. (2015). The Art of Electronics. Cambridge University Press.
5. Proakis, J. G., & Salehi, M. (2007). Communication Systems Engineering. Pearson.

Teaching Unit	Subject Title	Code	Semester
UEF1.1.2	Instrumentation and Sensors	INS	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	4/4

I. Course Objectives

- To provide an in-depth understanding of modern sensor technologies and their applications.
- To explore sensor interfacing, calibration, and data acquisition techniques.
- To study noise filtering and signal conditioning methods to improve sensor accuracy.
- To examine the role of sensors in unmanned autonomous systems.
- To develop hands-on experience with commonly used sensors in various applications.

II. Targeted Skills

- Selection and integration of sensors for various applications.
- Implementation of sensor calibration and interfacing techniques.
- Signal processing and noise filtering in sensor systems.
- Practical understanding of sensors used in autonomous systems.
- Ability to design and analyze sensor-based measurement systems.

III. Recommended prerequisites

- Basic electronics and circuit theory.
- Fundamentals of physics (mechanics, optics, and electromagnetism).
- Basics of signal processing and data acquisition.
- Introduction to programming.
- Knowledge of microcontrollers and embedded systems.

IV. Content

Chapter 1: Introduction to Sensor Technologies

1.1 Overview of Sensor Types and Applications

- Definition and importance of sensors
- Classification of sensors
- Applications in different fields

1.2 Optical Encoders

- Incremental Encoders
- Absolute Encoders
- Calibration

1.3 Accelerometers and Gyroscopes

- Working principles (MEMS, piezoelectric, capacitive sensors)

- Applications in motion tracking and robotics
- Calibration and error sources

1.4 GNSS , LiDAR and Radar

- GNSS definitions and types
- GPS fundamentals, accuracy, and error correction
- LiDAR working principles and applications
- Comparison of GPS and LiDAR for positioning
- RADAR working principles and applications

1.5 Camera Sensors

- Types of image sensors (CMOS, CCD)
- Image processing basics
- Role of cameras in autonomous systems

Chapter 2: Sensor Interfacing and Calibration

2.1 Basics of Sensor Interfacing

- Analog vs. digital sensors
- Communication protocols (I2C, SPI, UART, CAN)
- Data acquisition and synchronization

2.2 Sensor Calibration Techniques

- Importance of calibration
- Methods (Static, Dynamic, Multi-point Calibration)
- Software tools for calibration

2.3 Error Sources and Compensation

- Sources of errors (Drift, Bias, Noise, Temperature effects)
- Error correction techniques (Filtering, Sensor fusion)

Chapter 3: Noise Filtering and Signal Conditioning

3.1 Introduction to Signal Conditioning

- Signal amplification and attenuation
- Filtering techniques (Low-pass, High-pass, Band-pass, Notch filters)
- Signal isolation and impedance matching

3.2 Noise Sources and Reduction Methods

- Types of noise (thermal, shot, flicker, EM interference)
- Shielding and grounding techniques
- Software-based noise reduction

Chapter 4: Useful Sensors for Unmanned Autonomous Systems

4.1 Environmental Sensors

- Temperature sensors (Thermocouples, RTDs, Thermistors)
- Pressure sensors (Barometric, Absolute, Gauge)
- Humidity sensors and their applications

4.2 Motion and Navigation Sensors

- IMUs and their role in UAVs and ground robots
- Altitude sensors (Barometric, Ultrasonic, LiDAR-based)
- Applications of navigation sensors in autonomous vehicles

4.3 Proximity and Obstacle Detection Sensors

- Ultrasonic sensors
- Infrared sensors
- LiDAR and Radar in obstacle detection

Lab Work

Lab 1: Sensor Interfacing and Data Acquisition

Lab 2: Sensor Calibration and Error Compensation

Lab 3: Signal Processing and Noise Filtering

Lab 4: Obstacle Detection and Proximity Sensing

Lab 5: Sensor Integration in Autonomous Systems

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Fraden, J. (2016). *Handbook of Modern Sensors: Physics, Designs, and Applications*. Springer.
2. Webster, J. G. (2000). *The Measurement, Instrumentation, and Sensors Handbook*. CRC Press.
3. Wilson, J. (2004). *Sensor Technology Handbook*. Elsevier.
4. Groves, P. D. (2013). *Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems*. Artech House.
5. Carr, J. J. (2017). *Sensors and Circuits: Sensors, Transducers, Signal Conditioning, and Wireless Sensors*. Newnes.

Teaching Unit	Subject Title	Code	Semester
UEF1.1.2	Digital Signal Processing	DSP	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	4/4

I. Course Objectives

The objective of this course is to present tools to analyze the properties of a signal and examine what happens to it when it passes through a system. The last part concerns the acquisition of the concepts and notions of time-frequency analysis of non-stationary signals.

II. Targeted Skills

- Understanding and applying Fourier and Hilbert transforms.
- Designing and analyzing FIR and IIR filters.
- Performing correlation and convolution operations.
- Analyzing stochastic signals and their statistical properties.
- Applying time-frequency analysis techniques to real-world signals.

III. Recommended prerequisites

- Basic Mathematics : fonctions, integrals, etc.
- Probability and Statistics
- Basic programming skills (MATLAB/Python)

IV. Content

Chapter 1: Introduction

1. Signal Definition
2. Signal processing and its applications

Chapter 2: Deterministic signals

1. Continuous Time and Frequency Signals (Fourier Transform)
2. Discrete-Time and Continuous Frequency Signals (Sampling Theorem)
3. Discrete Time and Frequency Signals (Discrete Fourier Transform 'DFT', FFT)

Chapter 3: Signals and systems

1. Z Transform
2. Hilbert transform
3. Linear and stationary systems

Chapter 4: Synthesis of digital filters

1. FIR filter design methods
2. IIR filter design methods

Chapter 5: Random signals

1. Random Process
2. Stationary Signals
3. Ergodic Signals

Chapter 6: Introduction to Estimation and Spectral Analysis

1. Estimation elements: Bias, variance.
2. Correlation estimators
3. Periodogram
4. Welch
5. AR Modeling: Levinson's Algorithm

Chapter 7: Introduction to Time-Frequency Analysis

1. Concept of time-frequency representation
2. Short-Time Fourier Transform (STFT), Wavelet Transform, Time-frequency trade-offs
3. Instantaneous Frequency, Spectrogram, Wigner-Ville Distribution
4. Quadratic Time-Frequency Distributions
5. Cross-term reduction
6. Application examples

Laboratory Sessions

1. MATLAB/Octave Initiation/Signal Generation
2. Sampling, DFT/FFT
3. Digital Filtering
4. Spectral estimation
5. Time-frequency analysis

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Proakis, J.G. & Manolakis, D.G. "Digital Signal Processing: Principles, Algorithms, and Applications." Pearson, 2007.
2. Oppenheim, A.V. & Schafer, R.W. "Discrete-Time Signal Processing." Prentice Hall, 2010.
3. Hayes, M.H. "Statistical Digital Signal Processing and Modeling." John Wiley & Sons, 1996.
4. Cohen, L. "Time-Frequency Analysis." Prentice Hall, 1995.
5. Mitra, S.K. "Digital Signal Processing: A Computer-Based Approach." McGraw-Hill, 2010.

Teaching Unit	Subject Title	Code	Semester
UEM1.1.1	Introduction to Linux	ILI	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00		2h00	3/3

I. Course Objectives:

By the end of this course, students will:

- Understand the fundamentals of Linux and Ubuntu.
- Navigate the Linux file system and use the command line effectively.
- Perform essential system administration tasks.
- Write basic shell scripts to automate tasks.
- Set up and manage ROS2 on Ubuntu.

II. Targeted Skills:

Upon completing this course, students will have developed the following skills:

Technical Skills:

- Navigating and managing the Linux file system.
- Using the command line for file manipulation, system administration, and networking.
- Installing and managing software packages, including ROS.

Analytical Skills:

- Solving problems using command-line tools.
- Debugging and troubleshooting Linux.

Practical Skills:

- Setting up and configuring Ubuntu for robotics and software development.
- Writing and executing shell scripts to automate tasks.

III. Recommended prerequisites:

To succeed in this course, students should have:

- Familiarity with any operating system (Windows, macOS, etc.).
- No prior Linux experience is required.

IV. Content:

This course introduces the fundamentals of the Linux operating system, with a focus on Ubuntu. Students will learn to navigate the Linux environment, use the command line, and perform essential system administration tasks. The course is particularly relevant for those working with ROS and other robotics or software development tools.

Topics:

Chapter 1: Introduction to Linux and Ubuntu

- Overview of Linux and its distributions.
- Why Ubuntu? Importance in robotics and ROS.

- Installing Ubuntu: dual-boot, virtual machines, and live USB.

Chapter 2: Linux File System and Navigation

- Directory structure: '/home', '/etc', '/var', '/usr', etc.
- Basic commands: 'cd', 'ls', 'pwd', 'mkdir', 'rmdir', 'touch', 'cp', 'mv', 'rm'.
- File permissions and ownership: 'chmod', 'chown'.

Chapter3: Command Line Basics

- Shell and terminal usage.
- Command syntax and options.

Chapter4: Text Editing and Processing

- Text editors: 'nano', 'vim', and 'gedit'.
- File manipulation: 'cat', 'more', 'less', 'head', 'tail', 'grep', 'awk', 'sed'.

Chapter5: Package Management

- Installing and updating software: 'apt', 'dpkg'.
- Managing repositories: '/etc/apt/sources.list'.

Chapter6: System Administration

- User and group management: 'adduser', 'usermod', 'passwd'.
- Process management: 'ps', 'top', 'kill', 'systemctl'.
- Disk usage and management: 'df', 'du', 'mount', 'umount'.

Chapter7: Networking and Remote Access

- Basic networking commands: 'ifconfig', 'ping', 'ssh', 'scp'.
- Remote access: SSH and VNC.
- File sharing: 'rsync', 'sftp'.

Chapter8: Shell Scripting Basics

- Writing and executing shell scripts.
- Variables, loops, and conditionals.
- Automating tasks with scripts.

Chapter9: Ubuntu and ROS Integration

- Installing ROS packages and dependencies.
- Setting up ROS on Ubuntu.
- Managing ROS workspaces and packages.
- Troubleshooting common ROS and Ubuntu issues.

Labs:

1. Getting Started with Ubuntu and Linux Installation
2. Navigating the Linux File System and Command Line Mastery
3. System Administration and Package Management Essentials
4. Shell Scripting and Automation Tasks
5. ROS Integration and Advanced Ubuntu Configurations

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam

- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Remzi H. Arpaci-Dusseau and Andrea C. Arpaci-Dusseau, *Operating Systems: Three Easy Pieces*, Arpaci-Dusseau Books, 2018.
2. Andrew S. Tanenbaum and Herbert Bos, *Modern Operating Systems (4th Edition)*, Pearson, 2014.
3. Richard Blum and Christine Bresnahan, *Linux Command Line and Shell Scripting Bible (3rd Edition)*, Wiley, 2015.
4. Matthew Helmke, *Ubuntu Unleashed (6th Edition)*, Sams Publishing, 2021.
5. Michael Kerrisk, *The Linux Programming Interface*, No Starch Press, 2010.

Teaching Unit	Subject Title	Code	Semester
UEM1.1.1	Optimization Techniques	OPT	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h00	1h00	3/3

I. Course Objectives

- By the end of this course, students will:
- Understand the theoretical foundations of optimization.
- Formulate and solve optimization problems using appropriate techniques.
- Implement and evaluate optimization algorithms for real-world applications.
- Analyze and address challenges in optimization, such as scalability and non-convexity.

II. Targeted Skills

Upon completing this course, students will have developed the following skills:

Technical Skills:

Implementing optimization algorithms (e.g., gradient descent, simplex method). Using optimization libraries (e.g., SciPy, CVXPY).

Analytical Skills: Formulating and solving optimization problems. Evaluating and improving algorithm performance.

Practical Skills:

Designing and testing optimization solutions for real-world applications. Debugging and optimizing algorithms.

III/ Recommended Prerequisites

To succeed in this course, students should have:

- Basic knowledge of calculus and linear algebra.
- Familiarity with probability and statistics.
- Programming experience in Python.

IV/ Course Content

This course introduces the principles and methods of optimization, focusing on both theoretical foundations and practical applications. Students will learn to formulate and solve optimization problems in engineering.

1. Introduction to Optimization

- Definition and applications of optimization.

- Types of optimization problems: constrained vs. unconstrained, linear vs. nonlinear.
- Examples in engineering and machine learning.

2. Mathematical Foundations

- Convex sets and functions.
- Gradient, Hessian, and Taylor series approximation.
- Optimality conditions: first-order and second-order conditions.

3. Linear Programming

- Linear Program Formulation.
- Basic Solution Concepts – Convex Sets.
- Solution Methods for Linear Programming:
 - Graphical Solution Method
 - Simplex Method (Phase Method, Big-M Method)
- Duality in Linear Programming:
 - Dual Programs
 - Relationship between Primal and Dual Problems
 - Dual Simplex Method

4. Unconstrained Nonlinear Optimization

- Optimality Conditions:
 - Differential Case
 - Convex Case
- Algorithms for Unconstrained Optimization:
 - Gradient Descent and Steepest Descent Methods
 - Newton's Method and Quasi-Newton Methods (e.g., BFGS)
 - Convergence Analysis and Stopping Criteria

5. Constrained Nonlinear Optimization

- Necessary Optimality Conditions:
 - Equality Constraints and Lagrange Multipliers
 - Kuhn-Tucker Multipliers
 - Convex Case and Saddle Point Theorem
- Algorithms for Constrained Optimization:
 - Feasible Direction Method
 - Projected Gradient Method
 - Augmented Lagrangian Method
 - Arrow-Hurwicz Algorithm

6. Nonlinear Programming and Global Optimization

- Convex Optimization Problems.
- Interior-Point Methods.
- Challenges of Non-Convex Optimization.
- Heuristic Methods: Genetic Algorithms, Particle Swarm Optimization, Simulated Annealing.
- Applications in machine learning and control systems.

Labs

1. Linear Programming with the Simplex Method.
2. Gradient Descent for Function Minimization.
3. Constrained Optimization Using KKT Conditions.

4. Nonlinear Programming with Interior-Point Methods.
5. Heuristic Optimization: Genetic Algorithms & Particle Swarm Optimization PSO.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
 - The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Stephen Boyd & Lieven Vandenberghe – *Convex Optimization* (2004).
2. Dimitri P. Bertsekas – *Nonlinear Programming* (3rd Edition, 2016).
3. Edwin K. P. Chong & Stanislaw H. Zak – *An Introduction to Optimization* (4th Edition, 2013).
4. Jorge Nocedal & Stephen J. Wright – *Numerical Optimization* (2nd Edition, 2006).
5. Michel Bierlaire – *Optimization: Principles and Algorithms* (2015).
6. Ghojogh, B., Ghodsi, A., Karray, F., & Crowley, M. (2021). KKT conditions, first-order and second-order optimization, and distributed optimization: tutorial and survey. arXiv preprint arXiv:2110.01858.

Teaching Unit	Subject Title	Code	Semester
UET1.1.1	Ethics and Safety in AI and Robotics	ESAIR	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00			3/3

I. Course Objectives

- To introduce students to ethical theories and principles specific to AI and robotics.
- To explore ethical challenges related to bias, decision-making, and accountability in AI-driven systems.
- To analyze safety considerations in autonomous and unmanned systems.
- To understand societal impacts and regulatory frameworks governing AI and robotics.

II. Targeted Skills

- Identifying and analyzing ethical challenges in AI and robotics.
- Applying ethical decision-making frameworks to AI and autonomous systems.
- Understanding safety standards and risk assessment methodologies.
- Interpreting and adhering to ethical guidelines and regulatory policies.

III. Recommended Prerequisites

- Basic understanding of AI, machine learning, and robotics.
- Awareness of emerging technologies in automation and autonomous systems.
- Familiarity with legal and regulatory aspects of AI and robotics (optional).

IV. Content

Chapter 1: Introduction to Ethics in AI and Robotics

1.1 Definition and Importance of Ethics in AI and Robotics

- Ethical principles in AI and robotics.
- The role of ethics in shaping technological development.
- Ethical decision-making models.

1.2 Responsibilities of AI and Robotics Engineers

- Moral obligations of AI developers and roboticists.
- The balance between innovation and ethical considerations.
- Societal and professional expectations.

Chapter 2: Ethical Challenges in AI and Autonomous Systems

2.1 Bias and Fairness in AI

- Sources and consequences of AI bias.
- Algorithmic fairness and transparency.
- Strategies to mitigate bias in AI models.

2.2 Accountability and Decision-Making in Autonomous Systems

- Ethical implications of AI-driven decision-making.

- Who is responsible? (Developers, users, companies, policymakers).
- The "black box" problem in AI explainability.

2.3 Societal Impact of AI and Robotics

- Employment displacement and economic shifts.
- AI in warfare and law enforcement.
- Ethical concerns in healthcare and personal privacy.

Chapter 3: Safety Considerations in AI and Robotics

3.1 Risk Assessment in Autonomous Systems

- Identifying hazards in AI-driven technologies.
- AI safety frameworks and risk mitigation strategies.
- Case studies: Autonomous vehicles, industrial robots, and smart cities.

3.2 Privacy and Security Risks

- Data protection and ethical data usage.
- Cybersecurity risks in AI-powered systems.
- Regulatory compliance and industry best practices.

Chapter 4: Case Studies: Ethical and Safety Dilemmas in AI and Robotics

4.1 Real-World Ethical Failures

- Autonomous vehicle crashes and decision-making challenges.
- AI biases in hiring and law enforcement.
- Ethical concerns in AI-generated content.

4.2 Implementing Ethical and Safe AI Practices

- Ethical AI design principles.
- Transparency, explainability, and user trust.
- Industry and academic efforts in responsible AI development.

Chapter 5: Regulatory and Professional Frameworks

5.1 AI and Robotics Ethics Guidelines

- IEEE, EU AI Act, and other global ethical guidelines.
- Role of governmental and non-governmental organizations.

5.2 Legal and Regulatory Considerations

- AI liability and intellectual property rights.
- Privacy laws and data governance in AI applications.

5.3 The Future of AI Ethics and Safety

- Emerging challenges and new ethical debates.
- The role of AI governance in ensuring long-term safety.
- Public perception and trust in AI systems.

Evaluation Method

- Module average = 40% continuous assessment + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Bostrom, N., & Yudkowsky, E. (2014). The Ethics of Artificial Intelligence. Cambridge University Press.
2. Russell, S., & Norvig, P. (2021). Artificial Intelligence: A Modern Approach. Pearson.
3. Lin, P., Abney, K., & Bekey, G. (2011). Robot Ethics: The Ethical and Social Implications of Robotics. MIT Press.
4. IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems (2020). Ethical Considerations in AI and Robotics.

Teaching Unit	Subject Title	Code	Semester
UED1.1.1	Principles of Flight and Aeronautics	PFA	S5

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h30			1/1

I. Objectives

By the end of this course, students will:

- Understand the fundamental principles of aerodynamics, and stability in flight.
- Learn how aerodynamic forces affect aircraft and drone performance.
- Analyze the different flight regimes of unmanned aerial vehicles (UAVs).
- Explore the unique aerodynamic principles of terrestrial and underwater drones.
- Apply theoretical concepts through hands-on experiments and simulations.

II. Targeted Skills

Technical Skills

- Understanding the physics of flight and aerodynamic forces.
- Analyzing and designing airfoils, propulsion systems, and control surfaces.
- Evaluating UAV performance in different flight conditions.

Analytical Skills

- Applying mathematical models to describe aerodynamic behavior.
- Solving real-world problems related to unmanned systems in air, land, and water.

Practical Skills

- Conducting wind tunnel experiments and simulations.
- Using flight simulators and computational tools for UAV analysis.
- Testing UAV aerodynamics and stability in controlled environments.

III. Recommended Prior Knowledge

To succeed in this course, students should have:

- Basic knowledge of physics (Newtonian mechanics, fluid dynamics).
- Familiarity with calculus and linear algebra.
- Introductory knowledge of drones and their applications.

IV. Content

Chapter 1: Introduction to Flight and Aeronautics

- 1.1 History and evolution of flight
- 1.2 Applications of aeronautics in unmanned systems
- 1.3 Basic concepts: lift, drag, thrust, and weight

Chapter 2: Fundamentals of Aerodynamics

- 2.1 Fluid dynamics and Bernoulli's principle
- 2.2 Airfoil characteristics and lift generation
- 2.3 Drag types: parasitic and induced drag
- 2.4 Boundary layer and flow separation

Chapter 3: Aircraft and UAV Performance

- 3.1 Equations of motion for UAVs
- 3.2 Performance parameters: range, endurance, rate of climb
- 3.3 Stall, maximum lift-to-drag ratio, and glide performance
- 3.4 Energy management in UAV flight

Chapter 4: Stability and Control

- 4.1 Static and dynamic stability
- 4.2 Control surfaces: ailerons, rudder, and elevators
- 4.3 UAV control strategies and autopilot basics

Chapter 6: Flight Mechanics of Terrestrial and Underwater Drones

- 6.1 Aerodynamics of ground-effect vehicles
- 6.2 Hydrodynamics and buoyancy control for underwater drones
- 6.3 Stability and maneuvering in different environments

Chapter 7: High-Speed and High-Altitude Flight

- 7.1 Transonic, supersonic, and hypersonic regimes
- 7.2 UAV applications in high-altitude and high-speed environments
- 7.3 Challenges in aerodynamics and propulsion

Evaluation Method

- Module average = 40% continuous assessment + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. John D. Anderson Jr. – *Fundamentals of Aerodynamics* (6th Edition, 2016)
2. Bernard Etkin & Lloyd Duff Reid – *Dynamics of Flight: Stability and Control* (3rd Edition, 1995)
3. Brian L. Stevens & Frank L. Lewis – *Aircraft Control and Simulation* (3rd Edition, 2015)
4. Robert C. Nelson – *Flight Stability and Automatic Control* (2nd Edition, 1997)
5. Thomas J. Mueller – *Aerodynamics of Low Reynolds Number Flyers* (2001)

Detailed programs for the sixth semester

Teaching Unit	Subject Title	Code	Semester
UEF1.2.1	State Space Analysis and Control Design	SSACD	S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h00	1h00	4/4

I. Course Objectives :

By the end of this course, students will:

- Understand the principles of linear state space control systems.
- Model and analyze linear systems using state space approaches
- Design state feedback controllers and observers for real-world applications.

II. Targeted Skills:

Upon completing this course, students will have developed the following skills:

Technical Skills:

- Designing and implementing state feedback controllers and observers.

Analytical Skills:

- Solving control problems using state space methods.
- Evaluating system performance and stability.

Practical Skills:

- Using MATLAB/Simulink for simulation and analysis.

III. Recommended prerequisites:

To succeed in this course, students should have:

- Completion of Continuous Control Systems or equivalent knowledge.
- Familiarity with basic programming (e.g., MATLAB, Python).

IV. Content:

This course focuses on the analysis and design of discrete-time control systems, which are essential for digital control applications.

Topics:

Chapter1: Introduction to State space

- State vector.
- State space model.

Chapter2: Equilibrium and linearized state space model

- Finding LTI state space model using linearization.
- Solution of state space equation.

Chapter3: Controllability and observability Analysis

- Definitions.
- Controllability rank test,
- Observability rank test

Chapter4: Stability Analysis in state space

- System's Modes.
- Lyapunov Equation,
- Stability theorems for continuous and discrete time systems

Chapter5: State feedback control design

- Definition of state feedback control.
- Stabilization using state feedback control.
- Tracking using state feedback control,

Chapter6: Linear Quadratic Control design

- Definition of LQ criterion .
- Solution of the LQ control problem.
- Tracking using LQ control,

Chapter7: Observers and estimators Design

- Definition of observer and estimator,
- Different types of observer structures (open loop, Full order, reduced order and unknown input).
- Kalman Estimator,

Chapter8: State feedback based observer and LQG design

- State feedback using observed state
- Linear Quadratic Gaussian (LQG) controller

Labs:

1. State-Space Modeling of physical systems
2. Stabikity, Controllability and Observability Analysis
3. State Feedback and LQ Controller Design for LTI system
4. Observers Design
5. Stabilization and tracking for planner UAV

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Brogan, W. L. (1991). *Modern Control Theory* (3rd ed.). Prentice Hall.
2. Ogata, K. (2010). *Modern Control Engineering* (5th ed.). Prentice Hall.
3. Chen, C.-T. (1998). *Linear System Theory and Design* (3rd ed.). Oxford University Press.
4. Hespanha, J. P. (2018). *Linear Systems Theory*. Princeton University Press.
5. Friedland, B. (2012). *Control System Design: An Introduction to State-Space Methods*. Dover Publications.

Teaching Unit	Subject Title	Code	Semester
UEF1.2.1	Kinematics and Dynamics of Unmanned Systems	KDUS	S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	3/3

I. Course Objectives

By the end of this course, students will be able to:

- Analyze and understand the structure and mobility of unmanned systems, including aerial, ground, and underwater vehicles.
- Model unmanned systems using geometric, kinematic, and dynamic approaches.
- Develop proficiency in modeling, simulating, and analyzing unmanned systems.
- Compute forward and inverse kinematics for various unmanned platforms.
- Apply Lagrangian and Newton-Euler formalisms to derive dynamic models.
- Design and implement control algorithms for motion control of unmanned systems.
- Gain hands-on experience with simulation tools and real-world unmanned systems.

II. Targeted Skills

Upon completing this course, students will have developed the following skills:

- **Technical Skills:**
 - Proficiency in modeling and simulating unmanned systems.
 - Ability to implement kinematic and dynamic algorithms in software.
 - Experience with simulation tools and hardware platforms for unmanned systems.
- **Analytical Skills:**
 - Problem-solving in kinematics, dynamics, and control of unmanned systems.
 - Critical evaluation of system performance and limitations.
- **Practical Skills:**
 - Hands-on experience with simulation, control, and testing of unmanned systems.
 - Ability to design, prototype, and test unmanned systems in real-world scenarios.

III. Recommended Prerequisites

To succeed in this course, students should have:

- Mathematical Foundations: Linear algebra, calculus, and differential equations.
- Kinetics and dynamics of rigid bodies.
- Familiarity with feedback control and system dynamics.
- Programming Skills: Proficiency in Python, MATLAB, or C++.

IV. Content

The course provides a comprehensive and practical introduction to the kinematics, dynamics, and basic control of unmanned systems, with a focus on both theoretical foundations and real-world applications.

Chapter 1: Introduction to Unmanned Systems

- Overview of Unmanned Systems: History, Evolution, and Future Trends.
- Classification of Unmanned Systems:
 - Unmanned Aerial Vehicles (UAVs).
 - Unmanned Ground Vehicles (UGVs).
 - Unmanned Underwater Vehicles (UUVs).
- Applications in Defense, Agriculture, Environmental Monitoring, and Logistics.

Chapter 2: Unmanned System Structure

- Wheeled Robots: Differential drive, car-like, omnidirectional.
- Legged Robots (bipedal, quadrupedal): Stability, gait analysis, and dynamic walking.
- Aerial Robots: Quadrotors, fixed-wing drones.
- Underwater Robots: Propulsion and control challenges.

Chapter 3: Geometric Modeling

- Coordinate Systems and Reference Frames.
- Mobile Robot Pose: Position and Orientation.
- Rotation matrix and Homogeneous transformations.
- Orientation Description:
 - Euler Angles, Roll-Pitch-Yaw, Quaternions.
 - Manifolds.
- Transformations in 2D and 3D Space.

Chapter 4: Kinematic Modeling

- Kinematic Models for Unmanned Systems.
- Forward and Inverse Kinematics for UGVs: Differential drive, car-like, omnidirectional.
- Odometry Calculation.
- Non-holonomic Constraints and their implications.
- Forward and Inverse Kinematics for UAVs.
- Forward and Inverse Kinematics for UUVs.
- Singularity analysis.

Chapter 5: Dynamic Modeling

- Lagrange Formalism for Unmanned Systems.
- Newton-Euler Formalism.
- Dynamic Parameter Identification.
- Dynamic Models for UGVs, UAVs, and UUVs.

Chapter 6: Forces and Moments

- Gravitational Forces.
- Aerodynamic Forces and Moments.
- Propulsion Forces and Moments.
- Atmospheric Disturbances.
- Applications to drones.

Chapter 7: Motion Control

- Open-loop vs. closed-loop control.
- Pose control.
- Trajectory tracking and path following.

Labs:

All labs will involve hands-on projects using ROS2 or MATLAB, and simulation tools (CoppeliaSim, Gazebo, or Webots,). Students will work in teams to simulate, control, and test unmanned systems.

Lab 1: Introduction to ROS2 or MATLAB toolbox.

Lab 2: Introduction to Robotic Simulation using CoppeliaSim, Gazebo or Webots.

Lab 3: Kinematics of a Differential Drive Robot.

Lab 4: Kinematics of a Car-like Robot.

Lab 5: Dynamic Modeling of a Quadrotor.

Lab 6: Motion Control of an Unmanned System.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Beard, R. W., and McLain, T. W. *Small Unmanned Aircraft: Theory and Practice*. Princeton University Press, 2012.
2. Siegwart, R., Nourbakhsh, I. R., and Scaramuzza, D. *Introduction to Autonomous Mobile Robots*. MIT Press, 2011.
3. Corke, Peter. *Robotics, Vision and Control: Fundamental Algorithms in MATLAB*. Springer, 2017.
4. Fossen, Thor I. *Handbook of Marine Craft Hydrodynamics and Motion Control*. Wiley, 2011.
5. Lynch, Kevin M., and Park, Frank C. *Modern Robotics: Mechanics, Planning, and Control*. Cambridge University Press, 2017.
6. Spong, M. W., Hutchinson, S., and Vidyasagar, M. *Robot Modeling and Control*. Wiley, 2020.

Teaching Unit	Subject Title	Code	Semester
UEF1.2.2	Modeling and Control of Robotic Manipulators	MCRM	S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	3/3

I. Course Objectives

By the end of this course, students will be able to:

- Analyze and understand the structure of robot manipulators.
- Model robotic mechanisms using geometric, kinematic, and dynamic approaches.
- Develop proficiency in modeling, simulating, and analyzing robot manipulators.
- Compute forward and inverse kinematics using analytical and numerical methods.
- Apply Lagrange and Newton-Euler formalisms to derive dynamic models.
- Design and implement control algorithms for trajectory planning, motion control, and force control.
- Gain hands-on experience with robotic simulation tools and real-world robotic platforms.

II. Targeted Skills

Upon completing this course, students will have developed the following skills:

- **Technical Skills:**
 - Proficiency in modeling and simulating robot manipulators.
 - Ability to implement kinematic and dynamic algorithms in software.
 - Experience with robotic simulation tools and hardware platforms.
- **Analytical Skills:**
 - Problem-solving in kinematics, dynamics, and control of robot manipulators..
 - Critical evaluation of robotic system performance and limitations.
- **Practical Skills:**
 - Hands-on experience with robotic simulation, control, and testing.
 - Ability to design, prototype, and test robot manipulators in real-world scenarios.

III. Recommended Prerequisites

To succeed in this course, students should have:

- Mathematical Foundations: Linear algebra, calculus, and differential equations.
- Kinetics and dynamics of rigid bodies
- Familiarity with feedback control and system dynamics.
- Programming Skills: Proficiency in Python, MATLAB, or C++.

IV. Content

The course provides a comprehensive and practical introduction to the kinematics and dynamics of robotic systems, with a focus on both theoretical foundations and real-world applications.

Chapter 1: Introduction to Robotic Systems

- Overview of Robotics: History, Evolution, and Future Trends.
- Classification of Robotic Systems:
 - Manipulators (serial, parallel, collaborative robots).
 - Mobile Robots (wheeled, legged, aerial, underwater).
- Applications in Industry, Healthcare, Agriculture, and Space Exploration.

Chapter 2: Robot Manipulators Structure

- Structure and Components:
 - Articulated Mechanical Structure (AMS)
 - Base, arm, wrist, and end-effector.

- Degrees of Freedom (DoF) and workspace analysis.
- Joint Types: Revolute, prismatic, spherical, and universal joints.
- Redundancy, Singularities, and their implications.

Chapter 3: Geometric Modeling

- Coordinate Systems and Reference Frames.
- Robot Manipulator Pose.
- Rotation matrix and Homogeneous transformations.
- Orientation Description:
 - Euler Angles, Roll-Pitch-Yaw, Quaternions.
 - Manifolds.

Chapter 4: Kinematic Modeling

- Forward Kinematics:
 - Denavit-Hartenberg (D-H) parameters.
 - Joint space vs. Operational space.
 - Jacobian matrix and velocity propagation.
- Inverse Kinematics:
 - Analytical and numerical methods.
 - Pseudo-inverse Jacobian and Greville algorithm.
 - Redundancy resolution and singularity avoidance.
- Redundancy and singularity analysis.

Chapter 5: Dynamic Modeling

- Lagrange Formalism.
- Newton-Euler Formalism.
- Dynamic Parameter Identification.
- Dynamic Models for Robot Manipulators.

Chapter 7: Trajectory Planning

- Path and Trajectory.
- Joint Space Trajectories.
- Operational Space Trajectories.

Chapter 7: Motion Control

- Joint Space Control: PID, computed torque control.
- Computed Torque Feedforward Control.
- Operational Space Control.

Chapter 8: Force Control

- Force Control Strategies:
 - Inner position loop vs. Inner velocity loop.
 - Parallel force/position control.
- Applications in Assembly, Grasping, and Collaborative Robotics.

Labs:

All labs will involve **hands-on projects** using **ROS2** or **MATLAB**, and robotic simulation tools (CoppeliaSim or Gazebo). Students will work in teams to simulate, control, and test robot manipulators.

Lab 1: Introduction to ROS2 or MATLAB toolbox.

Lab 2: Introduction to Robotic Simulation using CoppeliaSim or Gazebo.

Lab 3: Kinematic Modeling of a Robot Manipulator.

Lab 4: Dynamic Modeling of a Robot Manipulator.

Lab 5: Motion Control of a Robot Manipulator.

Lab 6: Force Control in Robotic Grasping.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Siciliano, Bruno, et al. Robotics: Modelling, Planning and Control. Springer, 2010.
2. Spong, M. W., Hutchinson, S., and Vidyasagar, M. Robot Modeling and Control. Wiley, 2020.
3. Siegwart, R., Nourbakhsh, I. R., and Scaramuzza, D. Introduction to Autonomous Mobile Ro-bots. MIT Press, 2011.
4. Craig, John J. Introduction to Robotics: Mechanics and Control. Pearson, 2004.
5. Lynch, Kevin M., and Park, Frank C. Modern Robotics: Mechanics, Planning, and Control. Cambridge University Press, 2017.
6. Murray, Richard M., Li, Zexiang, and Sastry, S. Shankar. A Mathematical Introduction to Ro-botic Manipulation. CRC Press, 2017.

Teaching Unit	Subject Title	Code	Semester
UEF1.2.2	Actuators	ACT	S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	3/3

I. Course Objectives

- To provide an in-depth understanding of actuators and their applications in unmanned autonomous systems.
- To explore different types of actuators, including electric, hydraulic, pneumatic, and smart actuators.
- To analyze actuator control techniques and their integration into robotic and autonomous systems.
- To study the selection criteria for actuators based on application requirements.
- To develop hands-on experience with actuator implementation in unmanned systems.

II. Targeted Skills

- Understanding the working principles of various actuators.
- Selection and integration of actuators for autonomous systems.
- Implementation of control strategies for actuator operation.
- Troubleshooting and optimizing actuator performance.
- Practical experience with actuators used in UAVs, UGVs, and marine autonomous vehicles.

III. Recommended prerequisites

- Basic mechanics and physics (force, torque, motion dynamics).
- Fundamentals of electronics and electrical circuits.
- Basics of control systems and signal processing.
- Introduction to microcontrollers and embedded systems.

IV. Content

Chapter 1: Introduction to Actuators

1.1 Definition and Importance of Actuators

- Role of actuators in automation and robotics
- Classification of actuators
- Actuator performance parameters (speed, force, precision, efficiency)

1.2 Actuators in Unmanned Autonomous Systems

- Requirements for actuators in UAVs, UGVs, and marine vehicles
- Comparison of actuator types for different applications
- Power and efficiency considerations

Chapter 2: Electric Actuators

2.1 DC and Stepper Motors

- Working principles
- Control techniques (PWM, H-Bridge, microcontroller control)
- Applications in autonomous systems

2.2 Brushless DC Motors

- Principle of operation
- Advantages over brushed motors
- Sensorless and sensor-based control

2.3 Linear Actuators and Servo Motors

- Types and applications
- Position control techniques

- Integration with control systems

Chapter 3: Hydraulic and Pneumatic Actuators

3.1 Hydraulic Actuators

- Principles of hydraulics
- Components of hydraulic systems
- Applications in heavy-duty autonomous systems

3.2 Pneumatic Actuators

- Working principles
- Pneumatic circuits and control
- Applications in lightweight and high-speed systems

Chapter 4: Smart and Advanced Actuators

4.1 Piezoelectric and Shape Memory Alloy Actuators

- Principles of operation
- Applications in precision robotics
- Advantages and limitations

4.2 Soft Actuators and Artificial Muscles

- Basics of soft robotics
- Design and material considerations
- Implementation in bio-inspired systems

Chapter 5: Actuator Control and Integration

5.1 Control Strategies for Actuators

- PID control
- Model-based control techniques
- Adaptive and AI-based control methods

5.2 Sensor Feedback and Actuator Optimization

- Use of encoders and position sensors
- Performance tuning and troubleshooting
- Energy efficiency considerations

Chapter 6: Case Studies and Applications

6.1 Actuator Selection for UAVs, UGVs, and Marine Vehicles

- Comparative analysis of actuator choices
- Trade-offs in actuator selection
- Future trends in actuator technology

6.2 Hands-on Demonstrations and Simulations

- Practical experiments with electric and pneumatic actuators
- Software simulations for actuator control

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.

- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Spong, M. W., Hutchinson, S., & Vidyasagar, M. (2020). *Robot Modeling and Control*. Wiley.
2. Siciliano, B., & Khatib, O. (2016). *Springer Handbook of Robotics*. Springer.
3. Bolton, W. (2018). *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*. Pearson.
4. De Silva, C. W. (2007). *Sensors and Actuators: Control System Instrumentation*. CRC Press.
5. Pires, J. N. (2007). *Industrial Robotics: Programming, Simulation and Applications*. InTech.

Teaching Unit	Subject Title	Code	Semester
UEM1.2.1	Communication Systems	CSY	S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00	1h00	1h00	3/3

I. Course Objectives

This course provides an in-depth understanding of communication systems with a focus on their application in unmanned systems. It covers fundamental principles, protocols, and practical implementation techniques. Students will gain knowledge about wireless communication technologies, antenna design, and network optimization.

II. Targeted Skills

- Understanding the principles of wireless communication.
- Implementing and configuring communication protocols for unmanned systems.
- Designing and optimizing antenna systems for extended range.
- Setting up and troubleshooting communication networks.
- Applying theoretical knowledge in practical lab sessions.

III. Recommended prerequisites

- Basic electronics and circuit theory.
- Signals and systems.
- Digital signal processing fundamentals.
- Basic programming skills.

IV. Content

Chapter 1: Introduction to Communication Systems

- 1.1 Overview of communication systems and their applications
- 1.2 Signal propagation and the electromagnetic spectrum
- 1.3 Analog vs. digital communication

Chapter 2: Principles of Wireless Communication

- 2.1 Wireless channel characteristics
- 2.2 Modulation techniques (AM, FM, PM, QAM, OFDM)
- 2.3 Noise and interference in wireless communication
- 2.4 Link budget analysis

Chapter 3: Communication Protocols for Unmanned Systems

- 3.1 Wi-Fi: IEEE 802.11 standards and applications
- 3.2 ZigBee: IEEE 802.15.4 standard, advantages, and use cases
- 3.3 LoRa: Low-power wide-area networks (LPWAN) and implementation
- 3.4 LTE/5G: Cellular communication for unmanned systems
- 3.5 Comparison of protocols for different UAV applications

Chapter 4: Antenna Basics and Range Optimization

- 4.1 Antenna fundamentals and radiation patterns
- 4.2 Types of antennas used in unmanned systems
- 4.3 Signal range and power optimization
- 4.4 Interference mitigation techniques

Chapter 5: Network Design and Security for Unmanned Systems

- 5.1 Communication network architectures
- 5.2 Mesh networks for drones and robots
- 5.3 Security challenges and encryption techniques
- 5.4 Case studies of secure communication networks

Chapter 6: Practical Laboratory Sessions

- 6.1 Setting up a basic Wi-Fi communication network
- 6.2 Implementing LoRa for long-range communication
- 6.3 Configuring a ZigBee network for swarm robotics
- 6.4 Antenna testing and range optimization
- 6.5 Hands-on implementation of network security measures

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Goldsmith, A. "Wireless Communications." Cambridge University Press, 2005.
2. Rappaport, T.S. "Wireless Communications: Principles and Practice." Prentice Hall, 2001.
3. Stallings, W. "Wireless Communications & Networks." Pearson, 2005.
4. Holger, K. & Willig, A. "Protocols and Architectures for Wireless Sensor Networks." Wiley, 2005.
5. Larmo, A., Ratilainen, A., & Prytz, M. "LTE for Public Safety." Wiley, 2017.

Teaching Unit	Subject Title	Code	Semester
UEM1.2.1	Real Time Operating Systems	RTOS	S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00		2h00	3/3

I. Course Objectives

This course provides knowledge about real-time operating systems (RTOS) and their applications in embedded systems. Students will learn about the principles, design considerations, scheduling algorithms, and synchronization mechanisms involved in building real-time systems.

II. Targeted Skills

- Understand the fundamentals of real-time systems and their requirements.
- Learn about different types of real-time operating systems and their characteristics.
- Gain proficiency in designing, implementing, and analysing real-time scheduling algorithms.
- Explore synchronization techniques for real-time systems.
- Develop skills in programming, debugging and testing real-time applications.

III. Recommended prerequisites

- Understanding of computer architecture concepts, familiarity with programming and debugging.

IV. Content

Chapter 1: Introduction to Operating Systems

- Definition and functions of an operating system.
- Types of operating systems: batch processing, multiprogramming, time-sharing, distributed, and real-time.
- Processes and threads: definition, attributes, and states.
- Scheduling algorithms: FCFS, SJF, Round Robin, Priority Scheduling.

Chapter 2: Introduction to Real-Time Systems

- Definition and characteristics of real-time systems.
- Types of real-time systems: hard, firm, and soft real-time.
- Challenges and requirements in real-time systems design.

Chapter 3: Real-Time Operating System Basics

- Real-time operating systems concepts.
- Real-time operating system architecture.
- Tasks and processes in real-time systems.

Chapter 4: Real-Time Scheduling

- Basics of scheduling in real-time systems.
- Rate-monotonic scheduling (RMS).
- Earliest deadline first (EDF) scheduling.
- Comparison of different scheduling algorithms.

Chapter 5: Synchronization and Communication

- Mutual exclusion and its importance in real-time systems.
- Synchronization primitives: semaphores, mutexes, and condition variables.

- Inter-process communication mechanisms.
- Deadlock and priority inversion in real-time systems.

Chapter 6: Memory Management

- Memory management requirements in real-time systems.
- Techniques for memory allocation and deallocation.
- Memory protection and access control.

Chapter 7: Real-Time System Design Considerations

- Design patterns for real-time systems.
- Techniques for reducing system latency.
- Power management in real-time systems.

Chapter 8: Case Studies and Applications

- Real-world examples of real-time systems.
- Case studies in automotive, aerospace, medical, and industrial domains.
- Challenges and solutions in designing real-time systems for specific applications.

Laboratory Work

Lab1 (Task Scheduling Simulation):

- Simulate task-scheduling algorithms, such as Rate-Monotonic Scheduling (RMS) and Earliest Deadline First (EDF), and observe the behaviour of tasks over time, including missed deadlines and task preemptions.

Lab2 (RTOS Porting):

- Port a real-time operating system (e.g., FreeRTOS) to a specific hardware platform (e.g., STM32 Nucleo Boards).
- Build and run simple applications (e.g., led blink).

Lab3 (Interrupt Handling and Synchronization):

- Create a lab scenario where tasks are interrupted by hardware interrupts (e.g., timer interrupts).
- Use shared resources, semaphores, mutexes.

Lab4 (Implement a simple communication protocol for real-time systems):

- Define and implement a basic communication protocol (e.g., message passing or shared memory) for inter-task communication.
- Test the protocol's performance under different loads.

Lab5 (Develop a real-world application using an RTOS):

- Assign a project where students must design and implement a real-time application (e.g., a data acquisition system, a robotic controller, or a sensor network) using an RTOS platform.
- Students should define system requirements, partition tasks, implement task scheduling, and handle external events.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. "Real-Time Systems", Jane W. S. Liu.
2. "Real-Time Operating Systems Book 1: The Theory", Jim Cooling.

3. "Embedded Systems: Real-Time Operating Systems for Arm Cortex-M Microcontrollers", Jonathan Valvano.
4. "Embedded Systems Building Blocks: Complete and Ready-to-Use Modules in C", Jean J. Labrosse.
5. Online Resources: The FreeRTOS website: <https://www.freertos.org/>.

Teaching Unit	Subject Title	Code	Semester
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UEM1.2.2

Power Electronics

POE

S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h30	1h00	1h00	3/3

I. Course Objectives

Provide students with an in-depth understanding of power semiconductor devices and power converter topologies (AC/DC, DC/DC, AC/AC, DC/AC).

II. Targeted Skills

By the end of this module, students will be able to design, analyze, and implement power electronic circuits for embedded systems such as drones, electric vehicles, and industrial drives.

III. Recommended prerequisites

- Basic electronics (diodes, transistors, operational amplifiers)
- Fundamentals of electrical circuits (R, L, C, and simple AC analysis)
- Introductory knowledge of microcontroller-based control (PWM, gating signals)

IV. Content

CHAPTER 1: Introduction and Power Semiconductors

- Mechanical and Solid-State Relays: fundamentals, switching characteristics
- Power Semiconductor Devices: diode, thyristor (SCR), power transistor (BJT, MOSFET, IGBT)
- Static and dynamic characteristics, safe operating areas
- Heat dissipation, packaging, and cooling methods.
- Magnetism

CHAPTER 2: AC/DC Converters (Rectifiers)

- Uncontrolled Rectifiers: single-phase and three-phase with R, RL, RLE load; freewheel diode usage
- Controlled Rectifiers: single-phase and three-phase with R, RL, RLE load; thyristor-based control
- Analysis of average output voltage, ripple, and power factor

CHAPTER 3: DC/DC Converters (Choppers)

- Buck, Boost, and Buck-Boost Topologies
- Series vs. parallel choppers with various loads (R, RL, LC, RC, RLC)
- Continuous vs. discontinuous conduction mode
- PWM control strategies and efficiency considerations

CHAPTER 4: AC/AC Converters (Dimmers)

- Single-Phase AC Voltage Controllers: R, RL, RLC loads
- Three-Phase AC Voltage Controllers: unidirectional and bidirectional dimmers
- Applications: lighting control, motor speed control (AC induction motors).

CHAPTER 5: DC/AC Inverters

- Single-Phase Inverters: half-bridge, full-bridge with R, RL loads
- Three-Phase Inverters: 120°, 180° conduction modes, voltage control (SPWM)
- Harmonic analysis, THD, and filtering techniques.
- PWM control for inverters.
- Applications: motor drives, UPS, solar inverters.

CHAPTER 6: Motor Control and Drives

- DC motors vs. AC motors
- BLDC and Stepper motor control using PWM
- V/F control for AC motors
- Real-world applications (UAVs, robotics, electric vehicles)

CHAPTER 7: Power Supply Design and Energy Storage

- Linear vs. Switching Power Supplies
- Battery technologies (Li-ion, Li-Po, Lead-acid)
- Battery Management Systems (BMS)
- Wireless power transfer

CHAPTER 8: Applications and Advanced Topics

- Power factor correction (PFC) basics
- Battery charging circuits and advanced converter topologies (Resonant Power Conversion)
- Introduction to ESCs for brushless DC motors (BLDC), multi-level inverters
- Practical design considerations: EMI filters (CM + DM)
- Switched-Capacitor Convertors
- Soft-Switching (Switching losses + snubbers)
- Resonant Power Conversion
- Gate Drive, Level Shift, Layout

Lab works

Lab 1: Semiconductor Characterization.

Lab 2: Uncontrolled and Controlled Rectifiers.

Lab 3: DC/DC Buck and Boost Converters.

Lab 4: AC Voltage Control (Dimmer).

Lab 5: Single-Phase Inverter.

Lab 6: Advanced Converter or ESC for BLDC.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Mohan, N., "Power Electronics: Converters, Applications, and Design." Wiley, 2011.
2. Rashid, M.H., "Power Electronics: Circuits, Devices, and Applications." Pearson, 2017.
3. Erickson, R.W., Maksimovic, D., "Fundamentals of Power Electronics." Springer, 2001.
4. Wu, B., "High-Power Converters and AC Drives." Wiley, 2006.
5. Kazimierczuk, M.K., "Pulse-Width Modulated DC-DC Power Converters." Wiley, 2015.

Teaching Unit	Subject Title	Code	Semester
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UEM1.2.2

Introduction to Machine Learning

IML

S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00		2h00	3/3

I. Course Objectives

- To introduce fundamental concepts of machine learning and its applications.
- To differentiate between supervised and unsupervised learning techniques.
- To explore feature extraction techniques, particularly from sensor data.
- To provide an understanding of well-known ML algorithms and their applications.
- To develop hands-on experience in implementing ML models.

II. Targeted Skills

- Understanding and applying supervised and unsupervised learning techniques.
- Extracting and preprocessing features from sensor data.
- Implementing and tuning well-known machine learning algorithms.
- Evaluating and optimizing model performance.
- Practical experience with ML libraries such as Scikit-Learn and TensorFlow.

III. Recommended prerequisites

- Basic knowledge of linear algebra, probability, and statistics, partial derivatives, gradient descent algorithm.
- Familiarity with programming languages (preferably Python).
- Understanding of basic data structures and algorithms.
- Introduction to data science and signal processing concepts.

IV. Content

Chapter 1: Introduction to Machine Learning

1.1 Definition and Importance of Machine Learning

- Overview of AI and ML
- Real-world applications

1.2 Types and basics of Machine Learning

- Supervised learning
- Unsupervised learning
- Reinforcement learning (brief overview)
- Overfitting and underfitting concepts

Chapter 2: Supervised Learning Basics

2.1 Regression Techniques

- Linear regression
- Polynomial regression
- Evaluation metrics (RMSE, R^2 , etc.)

2.2 Classification Techniques

- Logistic regression
- Support Vector Machines (SVM)

- k-Nearest Neighbors (KNN)
- Naïve Bayes Classifier

Chapter 3: Unsupervised Learning Basics

3.1 Clustering Techniques

- K-Means
- Hierarchical clustering
- DBSCAN

3.2 Dimensionality Reduction

- Principal Component Analysis (PCA)
- t-SNE
- Singular Value Decomposition (SVD)

Chapter 4: Feature Extraction from Sensor Data

4.1 Introduction to Feature Engineering

- Importance of feature extraction
- Handling missing and noisy data

4.2 Feature Extraction Techniques

- Time-domain and frequency-domain analysis
- Statistical and model-based features
- Feature selection and transformation

Chapter 5: Well-Known Machine Learning Algorithms

5.1 Tree-Based Models

- Decision Trees
- Random Forest

5.2 Neural Networks and Deep Learning Basics

- Perceptron and Multi-Layer Perceptrons (MLP)
- Basics of deep learning frameworks (TensorFlow, PyTorch)
- Backpropagation Algorithm (Loss function (simplified model), Gradient descent, Regularization.).

5.3 Model Evaluation and Optimization

- Cross-validation
- Hyperparameter tuning
- Bias-variance tradeoff

Laboratory Sessions

- Lab 1: Implementing Regression and Classification Models
- Lab 2: Clustering and Dimensionality Reduction Techniques
- Lab 3: Feature Engineering and Data Preprocessing
- Lab 4: Neural Networks and Deep Learning Frameworks
- Lab 5: Model Evaluation and Hyperparameter Tuning

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Géron, A. (2019). *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*. O'Reilly Media.
2. Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. MIT Press.
3. Murphy, K. P. (2012). *Machine Learning: A Probabilistic Perspective*. MIT Press.
4. Hastie, T., Tibshirani, R., & Friedman, J. (2009). *The Elements of Statistical Learning*. Springer.
5. Bishop, C. M. (2006). *Pattern Recognition and Machine Learning*. Springer.

Teaching Unit	Subject Title	Code	Semester
UET1.2.1	Regulations and Standards for Unmanned Systems	RSUS	S6

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00			2/2

Course Objectives

By the end of this course, students will:

- Understand the legal and regulatory frameworks governing unmanned systems.
- Learn about international and national (Algerian) drone regulations.
- Analyze safety, certification, and operational requirements for UAVs, UGVs, and UUVs.
- Explore ethical and privacy considerations in drone operations.

II. Targeted Skills

Technical Skills

- Understanding airspace classifications and drone flight restrictions.
- Compliance with licensing and certification requirements.
- Navigating legal constraints for drone operations.

Analytical Skills

- Interpreting legal texts and regulatory documents.
- Evaluating the impact of regulations on drone applications.

Practical Skills

- Applying for permits and authorizations.
- Implementing risk assessment and safety protocols in operations.

III. Recommended Prior Knowledge

- Basic knowledge of drone technology and applications.
- Familiarity with aviation and transportation regulations.
- Awareness of ethical and legal considerations in technology.

IV. Content (Chapters and Subchapters)

Chapter 1: Introduction to Drone Regulations

- 1.1 Importance of regulations for unmanned systems
- 1.2 Overview of global regulatory bodies (ICAO, EASA, FAA, etc.)
- 1.3 Classification of unmanned systems and their regulatory differences

Chapter 2: Algerian Drone Regulations

- 2.1 National laws governing UAVs, UGVs, and UUVs
- 2.2 Airspace restrictions and operational limits in Algeria
- 2.3 Licensing, registration, and permit requirements
- 2.4 Penalties and legal consequences of non-compliance

Chapter 3: International Standards and Compliance

- 3.1 ICAO regulations for UAVs and integration into airspace
- 3.2 European (EASA) and U.S. (FAA) drone regulations
- 3.3 Certification standards (ISO, ASTM) for unmanned systems
- 3.4 Import/export and commercial use of drones

Chapter 4: Safety, Privacy, and Ethical Considerations

- 4.1 Risk assessment and safety management for drone operations
- 4.2 Privacy concerns and data protection laws
- 4.3 Ethical implications of autonomous drones
- 4.4 Counter-drone technologies and anti-drone regulations

Chapter 5: Regulatory Challenges and Future Trends

- 5.1 Challenges in harmonizing drone regulations globally
- 5.2 Emerging trends: Urban Air Mobility (UAM) and AI-driven autonomy
- 5.3 Future policies for BVLOS (Beyond Visual Line of Sight) and swarm operations

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. **International Civil Aviation Organization (ICAO)** – *Manual on Remotely Piloted Aircraft Systems (RPAS)* (2018)
2. **European Aviation Safety Agency (EASA)** – *EU Drone Regulations & U-Space Framework* (2021)
3. **Federal Aviation Administration (FAA)** – *Part 107 Small UAS Rule* (2016)
4. **Algerian Civil Aviation Authority (DACM)** – *National Regulations for Drone Operations in Algeria* (Latest Version)
5. **ISO 21384-3:2019** – *Unmanned Aircraft Systems – Part 3: Operational Procedures*

Teaching Unit	Subject Title	Code	Semester
UED1.2.1	Capstone Project I	CP-I	S6

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH		1h00	2/2

I. Course Objectives

- Form teams and identify project ideas.
- Conduct feasibility analysis and initial design documentation.
- Establish milestones and present progress to faculty advisors.

II. Targeted Skills

- Teamwork and collaboration.
- Problem identification and solution structuring.
- Technical writing and presentation skills.
- Project planning and feasibility assessment.

III. Recommended prerequisites

- Fundamentals of unmanned systems.
- Basic project management.
- Technical writing and documentation.

IV. Content

- 1. Team Formation and Brainstorming**
 - Introduction to project selection.
 - Team roles and responsibilities.
 - Idea generation techniques.
- 2. Feasibility Analysis and Initial Design Documentation**
 - Market and technical feasibility.
 - Risk assessment.
 - Drafting project proposals and documentation.
- 3. Regular Milestones and Faculty Presentations**
 - Setting up project goals and deadlines.
 - First milestone presentation.
 - Refining project scope based on feedback.

Evaluation Method

- Module average = 100% continuous assessment
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

- Project Management for Engineering and Technology by J. Nicholas
- Engineering Design: A Project-Based Introduction by Clive Dym

Teaching Unit	Subject Title	Code	Semester
UED1.2.1	Training Internship I	TI-I	S6

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH			1/1

I. Course Objectives

- Introduce students to professional work environments.
- Develop basic technical and soft skills in an industry setting.
- Understand company structure, workflow, and project dynamics.

II. Targeted Skills

- Professional communication.
- Basic technical proficiency.
- Adaptability to work environments.
- Teamwork and collaboration.

III. Recommended prerequisites

- Fundamentals of unmanned systems.
- Basic project management principles.

IV. Content

- 1. Introduction to the Company**
 - Company overview and mission.
 - Workplace safety and regulations.
- 2. Observation and Shadowing**
 - Understanding team roles and responsibilities.
 - Exposure to ongoing projects.
- 3. Hands-on Experience**
 - Assisting in minor tasks and operations.
 - Learning basic tools and methodologies.
- 4. Final Review and Feedback**
 - Supervisor feedback session.
 - Internship report preparation.

Evaluation Method

- Module average = 100% continuous assessment
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

- The Internship, Practicum, and Field Placement Handbook by Brian N. Baird
- Professionalism: Skills for Workplace Success by Lydia E. Anderson

Detailed programs for the seventh semester

Teaching Unit	Subject Title	Code	Semester
UEF2.1.1	Multivariable Control Systems Design	MCSD	S7

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h00	1h00	3/3

I. Course Objectives

By the end of this course, students will:

- Understand the challenges multi input multi output (MIMO) systems.
- Analyze interaction and behavior of MIMO systems.
- Design and implement multivariable control using transfer function matrix methods.

II. Targeted Skills

Upon completing this course, students will have developed the following skills:

- Technical Skills:
 - Analyzing and controlling linear MIMO systems.
 - Implementing advanced MIMO control techniques.
- Analytical Skills:
 - Solving complex multivariable control problems.
- Practical Skills:
 - Using MATLAB/ Python for MIMO system simulation.

III. Recommended prerequisites

Strong mathematical background (calculus, linear algebra, differential equations)

IV. Content/ Content

Chapter 1: Introduction to Multivariable Control Systems

- Definition of multi input /multi output systems .
- Examples of MIMO systems in engineering.

Chapter 2: Frequency domain Modeling of MIMO Systems

- Transfer function Matrix .
- Poles and Zeros of TFM.
- Interaction Analysis

Chapter 3: Gain of TFM

- Norms of Signals and Systems.
- Singular Values of TFM and induced gain.
- Condition number of TFM and scaling

Chapter 4: I/O Stability Analysis

- Multivariable Nyquist theorem.
- Small Gain theorem
- Passivity theorem.

Chapter 5: Performance Analysis of MIMO control system

- Sensitivity and Complementary sensitivity functions.
- Disturbances rejection and references tracking constraints.
- Open loop gain constraints for performances

Chapter6: Robustness Analysis.

- Modelling errors and robustness in stability/performances.
- Delay and Modulus's Margins.
- Open loop gain constraints for Robustness
- Tradeoff performance/Robustness

Chapter 7: Loop shaping Controller Design

- Bode ideal open loop TFM.
- Loop matching Design.
- Mixed sensitivity Design

Chapter 8: H infinity Controller Design

- Standard H infinity control problem.
- Sub optimal Solution.
- Optimal Solution

Labs:

1. TFM modeling, interaction and decoupling design for 04 tanks system
2. Decentralized PID control for TITO system
3. Design by loop shaping for MIMO system
4. Mixed sensitivity design for 04 tanks system
5. H_infinity control design for planner UAV

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
 - The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. S. Skogestad and I. Postelwait, Multivariable Feedback Control :Analysis and design , J. Weilly, 2006.
2. P. Albertos and A. Sala, Multivariable Control Systems:An Engineering Approach , Springer , 2004.
3. S.P. Bhattacharatya and L.H. Keel, Linear Multivariable Control Systems, Cambridge University Press, 2022.
4. Liansheng Tane, A Generalized framework for Linear Multivariable Control , Butterworth-Heinemann, 2017.

Teaching Unit	Subject Title	Code	Semester
UEF2.1.1	Computer Vision	CV	S7

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00		1h30	3/3

I. Course Objectives

This course aims to provide students with a comprehensive understanding of computer vision fundamentals, including image processing, feature detection, motion analysis, and 3D vision. By the end of the course, students will be able to implement key computer vision algorithms and apply them to real-world applications.

II. Targeted Skills

- Understanding the principles of image formation and processing.
- Applying filtering techniques and edge detection methods.
- Implementing feature extraction and matching algorithms.
- Utilizing optical flow for motion detection.
- Understanding and applying object detection models such as YOLO and R-CNN.
- Performing camera calibration and 3D vision tasks.
- Gaining hands-on experience in computer vision through practical labs.

III. Recommended prerequisites

- Linear algebra and matrix operations.
- Basic calculus and probability.
- Programming skills in Python.
- Knowledge of fundamental image processing concepts.
- Familiarity with machine learning basics.

IV. Content

This course introduces the fundamental concepts and techniques of computer vision, focusing on image processing, feature extraction, object recognition, motion analysis, and 3D vision. Students will gain hands-on experience with computer vision algorithms and applications.

Chapter 1: Introduction to Computer Vision

- 1.1 Overview of computer vision applications
- 1.2 Relationship with artificial intelligence and robotics
- 1.3 Basic concepts: pixels, images, and color spaces

Chapter 2: Image Formation and Representation

- 1.1 Image acquisition: cameras and sensors.
- 1.2 Image representation: pixels, color spaces (RGB, grayscale, HSV).
- 1.3 Image transformations: scaling, rotation, and translation.

Chapter 3: Image Processing Basics

- 2.1 Image filtering: convolution, smoothing, and sharpening.
- 2.2 Edge detection methods (Sobel, Canny, Laplacian)
- 2.3 Morphological operations: erosion, dilation, and opening/closing.

Chapter 4: Feature Extraction and Matching

- 3.1 Keypoint detection: Harris corner detector, SIFT, and SURF.
- 3.2 Feature descriptors: HOG, ORB, and BRIEF.
- 3.3 Feature matching (FLANN, brute-force) and RANSAC.

Chapter 5: Image Segmentation

- 4.1 Thresholding and region-based segmentation.
- 4.2 Clustering-based segmentation: k-means and mean-shift.
- 4.3 Contour detection and active contours.

Chapter 6: Object Detection and Recognition

- 4.1 Template matching and sliding window approaches.
- 4.2 Haar cascades and Viola-Jones algorithm.
- 4.3 Introduction to deep learning-based object detection (e.g., YOLO, SSD).

Chapter 7: Motion Detection and Optical Flow

- 4.1 Introduction to motion analysis
- 4.2 Optical flow concepts (Lucas-Kanade, Farneback)
- 4.3 Object tracking techniques (Mean-Shift, KCF)

Chapter 8: Camera Calibration and 3D Vision

- 5.1 Camera models and intrinsic parameters
- 5.2 Extrinsic parameters and pose estimation
- 5.3 Stereo vision and depth estimation
- 5.4 Structure from motion (SfM).
- 5.5 Point cloud processing and 3D reconstruction.

Chapter 9: Applications and Case Studies

- 4.1 Face detection and recognition.
- 4.2 Optical character recognition (OCR).
- 4.3 Real-world challenges: lighting, occlusion, and scalability.

Lab Works

Hands-on implementation of computer vision algorithms using Python and OpenCV.

- Implementing edge detection and feature extraction in OpenCV
- Feature matching using SIFT, SURF, and ORB
- Optical flow-based motion detection
- Camera calibration and depth estimation

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Szeliski, R. "Computer Vision: Algorithms and Applications." Springer, 2010.
2. Forsyth, D.A., Ponce, J. "Computer Vision: A Modern Approach." Pearson, 2011.
3. Gonzalez, R.C., Woods, R.E. "Digital Image Processing." Pearson, 2018.
4. Goodfellow, I., Bengio, Y., Courville, A. "Deep Learning." MIT Press, 2016.
5. OpenCV Documentation (<https://docs.opencv.org/>).

Teaching Unit	Subject Title	Code	Semester
UEF2.1.1	System Identification	PID	S7

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00	1h00	1h00	3/3

I. Course Objectives:

This course aims to give a presentation of techniques in advanced process modelling, identification, prediction, and parameter estimation for the implementation and analysis of industrial systems. It covers applications for the identification of linear and non-linear systems of multivariable systems in order to ensure a model based design of controllers.

II. Targeted Skills:

Upon completing this section, students will have developed the following skills:

- Understand identification techniques and parameters estimation algorithms.
- Be able to use parameters estimation algorithms to determine system's parameters
- Technical Skills:
 - Use of identification techniques for control model determination
- Analytical Skills:
 - Use of parameters estimation algorithms to recover system's parameters
- Practical Skills:
 - Using MATLAB/Simulink for simulation and analysis

III. Recommended prerequisites / Prerequisites:

- Basic knowledge of optimization
- Basic knowledge of dynamic systems, differential equations, and signal analysis.
- Programming skills and experience using simulation tools such as MATLAB or Python.

IV. Content/ Content:

Topics:

1 Introduction to Identification

- 1.1 Where are models needed?
- 1.2 What kinds of models are there?
 - Knowledge model, Behavioral model, Parametric model.
 - Linear and nonlinear models.
 - Deterministic models and stochastic models.
- 1.3 Steps of identification
- 1.4 Commonly used input signals

2 Non Parametric Identification Methods

- 2.1 Impulse and Step Response.
- 2.2 Correlation methods

2.3 Spectral analysis

3 Linear Regression

- 3.1 Deterministic and Stochastic models
- 3.2 Method of least squares
- 3.3 Recursive LS method
- 3.4 RLS with exponential forgetting.
- 3.5 Model order determination

4 Estimation of Parameters

- 4.1 Prediction error methods: (First-order methods, Second-order methods , Step size, Levenberg-Marquardt algorithm)
- 4.2 Instrumental Variable method
- 4.3 Likelihood method
- 4.4 Convergence and Consistency

5 Non-linear System Identification

- 5.1 Polynomial NARMAX method
- 5.2 Machine Learning methods

6 Identification in Practice

- 6.1 Error filtering
- 6.2 Model Structure Validation
- 6.3 Order Estimation
- 6.4 Identification in closed loop

Labs:

Lab Work1: Apply identification methods to real dynamic systems using real-world data.

Lab Work 2: "Identification of a model using classical identification methods (Broida method and Strejc method).

Lab Work 3 : Implement modern identification methods using simulation software (e.g., MSFS, FSUIPC, MATLAB, Python).

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. System Identification: Theory for the User by Lennart Ljung, second Edition, Pearson, 1998.
2. Identification of Dynamic Systems: An Introduction with Applications by Rolf Isermann, Springer, 2011.
3. Applied System Identification by Ashish Tewari.
4. A.K. Tangirala, "Principles of System Identification : Theory and Practice" CRC Press, 2018
5. Y. Bar-Shalom, X. R. Li, T. Kirubarajan, "Estimation with Applications to Tracking and Navigation", John Wiley & Sons 2004

Teaching Unit	Subject Title	Code	Semester
UEF2.1.2	Fundamentals of Autonomous Navigation	FAN	S7

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h00	1h00	3/3

I. Course Objectives/ Course Objectives:

By the end of this course, students will:

- Understand the fundamental principles of mobile robotics and autonomous navigation.
- Gain proficiency in using ROS2 for robotics development.
- Develop skills in modeling robot motion and performing coordinate transformations.
- Implement and evaluate localization, mapping, and basic path planning algorithms.
- Apply sensor fusion techniques to improve robot perception and localization.
- Design and test basic autonomous navigation systems in simulated and real-world environments.

II. Targeted Skills:

Upon completing this section, students will have developed the following skills:

- Technical Skills:
 - Proficiency in ROS2 for robotics development.
 - Ability to implement and debug basic autonomous navigation algorithms.
 - Experience with sensor integration and data fusion.
- Analytical Skills:
 - Problem-solving in localization, mapping, and obstacle avoidance.
 - Critical evaluation of algorithm performance.
- Practical Skills:
 - Hands-on experience with robotics simulation tools.
 - Ability to design and test basic autonomous systems in real-world experimentation.

III. Recommended prerequisites:

- Basic knowledge of linear algebra (vectors, matrices, transformations).
- Familiarity with programming in Python or C++.
- Understanding of fundamental physics concepts (e.g., kinematics, dynamics).
- Prior exposure to control systems is helpful but not required.

IV. Content:

This course introduces the foundational concepts and technologies behind autonomous navigation in mobile robotics. Students will gain hands-on experience with the Robot Operating System (ROS2) and explore key components such as perception, localization, mapping, and basic path planning.

Chapter 1: Introduction to Mobile Robotics

- Evolution of mobile robotics.
- Types of locomotion (wheeled, legged, aerial, etc.).
- System architecture: hardware and software components.

- Real-world applications: autonomous vehicles, drones, warehouse robots, and more.

Chapter 2: Robot Operating System (ROS2)

- Basic principles and architecture.
- Key tools: nodes, topics, services, and actions.
- Practical use cases and examples.

Chapter 3: Mobile Robot Kinematics and control

- Robot pose, rotation matrix, and homogeneous transformations.
- Non-holonomic Constraints and their implications.
- Forward and Inverse Kinematics for Mobile Robots.
- Comparative analysis of kinematics for different mobile robot configurations.
- Pose Control of a Differential Drive Robot.

Chapter 4: Core Components of Autonomous Navigation

- Perception: Sensor data processing (LiDAR, cameras, IMU, etc.).
- Localization: Techniques for determining robot position.
- Planning: Basic path planning and obstacle avoidance.
- Control: Motion control and trajectory execution.

Chapter 5: Perception

- Sensors for mobile robotics : Encoders, IMU, GPS, LiDAR, cameras, etc.
- Sensor Classification: proprioceptive/exteroceptive and passive/active.
- Sensor Calibration and Data Acquisition.
- Representing Uncertainty.
- Feature Extraction.

Chapter 6: Basic Localization Techniques

- Odometry and dead reckoning.
- Inertial localization and GPS integration.
- Sensor fusion: Kalman filters and Extended Kalman Filters (EKF).
- Localization using exteroceptive sensors (e.g., LiDAR, cameras).

Chapter 7: Mapping

- Environment modeling and grid maps.
- Introduction to Simultaneous Localization and Mapping (SLAM).

Chapter 8: Basic Path Planning and Obstacle Avoidance

- Graph search methods for planning (e.g., A*, Dijkstra).
- Potential field methods for obstacle avoidance.

Labs:

Lab 1: Introduction to ROS2 and Mobile Robotics Simulation

Lab 2: Kinematics, Odometry, and Open-loop control using real or simulated platforms.

Lab 3: Pose Control for a Differential Drive Robot using ROS2

Lab 4: Sensor Fusion for Localization

Lab 5: Obstacle Avoidance Implementation with ROS2

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
 - The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Siegwart, R., Nourbakhsh, I.R., & Scaramuzza, D. (2011). *Introduction to Autonomous Mobile Robots*. MIT Press.
2. Thrun, S., Burgard, W., & Fox, D. (2005). *Probabilistic Robotics*. MIT Press.
3. LaValle, S.M. (2006). *Planning Algorithms*. Cambridge University Press.

Teaching Unit	Subject Title	Code	Semester
UEF2.1.2	Filtering and Recursive Estimation	FRE	S7

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h00	1h00	3/3

I. Course Objectives:

By the end of this course, students will:

- Understand the principles of recursive estimation and Bayesian filtering.
- Analyze and address challenges in state estimation, such as nonlinearity and non-Gaussian noise.
- Implement and evaluate Kalman filters, EKF, and particle filters.
- Apply recursive estimation techniques to real-world problems in robotics and autonomous systems.

II. Targeted Skills:

Upon completing this course, students will have developed the following skills:

- **Technical Skills:**
 - Implementing recursive estimation algorithms (e.g., Kalman filter, EKF, particle filter).
 - Using Python or C++ for simulation and analysis.
- **Analytical Skills:**
 - Solving state estimation problems using Bayesian methods.
 - Evaluating and improving filter performance.
- **Practical Skills:**
 - Designing and testing estimation systems for real-world applications.
 - Debugging and optimizing filtering algorithms.

III. Recommended prerequisites:

- Basic knowledge of probability and statistics.
- Introductory knowledge of dynamic systems and control theory.
- Programming experience in Python or C++.

IV. Content:

This course introduces the principles and techniques of recursive estimation and Bayesian filtering, which are essential for state estimation in dynamic systems. Students will learn to apply these methods to problems in robotics, autonomous systems, and signal processing.

Topics:

Chapter1: Introduction to State Estimation

- Definition and applications of recursive estimation.
- Examples in robotics, tracking, and sensor fusion.

Chapter2: Kalman Filter

- Linear Gaussian systems and assumptions.
- Derivation of the Kalman filter.
- Applications in tracking and localization.

Chapter3: Extended Kalman Filter (EKF)

- Nonlinear systems and linearization techniques.
- Derivation and implementation of the EKF.
- Applications in robotics and autonomous vehicles.

Chapter4: Unscented Kalman Filter (UKF) for nonlinear systems.

Chapter5: Bayesian Probability Theory

- Bayes' theorem and conditional probability.
- Prior, likelihood, and posterior distributions.
- Bayesian inference and prediction.

Chapter6: Recursive Bayesian Estimation

- State-space models and Markov assumptions.
- Prediction and update steps in recursive estimation.
- Examples of recursive estimation in dynamic systems.

Chapter7: Particle Filter

- Monte Carlo methods and importance sampling.
- Sequential Monte Carlo (SMC) and particle filtering.
- Applications in non-Gaussian and multimodal systems.

Chapter8: Applications and Case Studies

- Sensor fusion in autonomous systems.
- Target tracking and localization.
- Real-world challenges: computational efficiency and robustness.

Labs:

Hands-on implementation of recursive estimation and filtering algorithms using Python or C++.

Laboratory Work

Lab 1: Introduction to Kalman Filtering

Lab 2: Extended Kalman Filter for Nonlinear Systems

Lab 3: Unscented Kalman Filter (UKF) for Nonlinear Systems

Lab 4: Particle Filtering for Non-Gaussian Systems

Lab 5: Sensor Fusion Using Recursive Estimation

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. S. Thrun, W. Burgard, & D. Fox – *Probabilistic Robotics* (MIT Press, 2005)
2. R. E. Kalman – *A New Approach to Linear Filtering and Prediction Problems* (ASME, 1960)
3. D. Simon – *Optimal State Estimation: Kalman, H_∞ , and Nonlinear Approaches* (Wiley, 2006)
4. B. D. O. Anderson & J. B. Moore – *Optimal Filtering* (Dover, 2005)
5. H. W. Sorenson – *Kalman Filtering: Theory and Application* (IEEE Press, 1985)

Teaching Unit	Subject Title	Code	Semester
UEF2.1.2	Advanced Embedded Systems Design	AESD	S7

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH 1h30		1h30	3/3

I. Course Objectives

- To deepen knowledge in embedded systems by introducing Digital Signal Processing (DSP)
- Build a background on Field Programmable Gate Arrays (FPGA).
- To explore advanced embedded system design techniques for high-performance applications.
- To gain practical experience in designing and testing complex embedded control systems.

II. Targeted Skills

- Understanding DSP fundamentals and applications in embedded systems.
- Implementing FPGA-based designs for real-time processing.
- Developing high-performance embedded control systems.
- Utilizing hardware acceleration techniques for embedded applications.

III. Recommended prerequisites

- Completion of "Embedded Systems Design" course.
- Proficiency in C/C++
- Understanding of microcontroller/microprocessor architectures and RTOS.
- Familiarity with signal processing concepts.

IV. Content

Chapter 1: Introduction to Advanced Embedded Systems

- 1.1. Overview of Advanced Embedded Architectures
- 1.2. Applications of DSP and FPGA in Embedded Systems
- 1.3. Performance Considerations in Embedded Design

Chapter 2: Digital Signal Processing for Embedded Systems

- 1.1. Fundamentals of DSP: Sampling, Filtering, and Transforms
- 1.2. Real-Time Signal Processing Techniques
- 1.3. Implementing DSP Algorithms on Embedded Platforms

Chapter 3: Circuits logiques programmables

- 1.1. Introduction aux circuits logiques programmables
- 1.2. Principes programmation et de fonctionnement
- 1.3. Technologies de programmation (Fusible, Anti-fusible, SRAM ...etc.)
- 1.4. Circuits PAL, PLA, GAL et CPLD

Chapter 4: Circuits FPGA

- 1.1. Architecture des FPGA
- 1.2. Modes de programmation des FPGA (maitre, esclave, série, parallèle, JTAG ...etc.)

1.3. Reconfiguration partielle

Chapter 5: Introduction aux HDL

- 1.1. Timeline de conception des circuits numériques
- 1.2. Définition des langages de description matériel
- 1.3. Différence avec les langages informatiques traditionnels
- 1.4. Considérations de conception en HDL

Chapter 6: VHDL (or Verilog) Design Units

- 1.1. Invariants
- 1.2. Description organisation
- 1.3. Standard Libraries
- 1.4. Entity declaration
- 1.5. Architecture
- 1.6. Signal and Variable Assignments

Chapter 7: VHDL Assignment

- 1.1. Concurrent Statements
- 1.2. Assignment types
- 1.3. Concurrent signal assignment
- 1.4. Conditional signal assignment
- 1.5. Selected signal assignment
- 1.6. Process statements

Chapter 8: VHDL Sequential Statements

- 1.1. Signal assignment statement
- 1.2. “if” statement
- 1.3. “case” statement

Chapter 9: VHDL Operators

- 1.1. Shift Operator
- 1.2. Concatenation operator

Chapter 10: Data Objects

- 1.1. Types of Data Objects
- 1.2. Signals vs. Variables
- 1.3. Standard Data Types
- 1.4. User-Defined Types
- 1.5. Commonly Used Types and Std_logic Type

Chapter 11: Finite State Machine

- 1.1. FSM Example
- 1.2. FSM Design Using VHDL

Chapter 12: Structural Modeling In VHDL and Looping Constructs

- 1.1. VHDL Modularity with Components
- 1.2. Construction of parametrised components (Generics)
- 1.3. Generic Map
- 1.4. Generate Statement
- 1.5. Looping Constructs

Practical Lab: Building Advanced Embedded Control Systems

- 1 Implementing a DSP-Based Embedded Application
- 2 Designing FPGA-Based Embedded System
- 3 Debugging and Optimizing High-Performance Embedded Applications

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Bryan Mealy, Fabrizio Tappero, "Free Range VHDL" 2013.
http://freerangefactory.org/pdf/free_range_vhdl.pdf
2. Smith, S. W. (2003). *The Scientist and Engineer's Guide to Digital Signal Processing*. California Technical Publishing.
3. Wolf, W. (2004). *FPGA-Based System Design*. Pearson.
4. Yiu, J. (2015). *The Definitive Guide to ARM Cortex-M Processors*. Newnes.
5. Maxfield, C. (2004). *The Design Warrior's Guide to FPGAs: Devices, Tools, and Flows*. Elsevier.
6. Oppenheim, A. V., & Schafer, R. W. (2009). *Discrete-Time Signal Processing*. Pearson.

Teaching Unit	Subject Title	Code	Semester
UEM2.1.1	Neural Networks and Deep Learning	NNDL	S7

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00		2h00	3/3

I. Course Objectives

- Provide a comprehensive introduction to deep learning fundamentals.
- Enable students to understand and implement neural networks, with a focus on CNN architectures.
- Develop the ability to design, train, and optimize deep learning models for practical image processing tasks.
- Introduce unsupervised learning techniques through autoencoders and variational autoencoders (VAEs).

II. Targeted Skills

- Understand deep learning theory and neural network structures.
- Implement activation functions, optimization methods, and regularization techniques.
- Design and implement Convolutional Neural Networks (CNNs) for image classification.
- Build autoencoder models for data compression and noise reduction.
- Set up and utilize GPU environments to accelerate model training.

III. Recommended Prerequisites

- Successful completion of an "Introduction to Machine Learning" course.
- Solid background in linear algebra, probability, and statistics.
- Proficiency in Python and familiarity with libraries like NumPy and Pandas.
- Proficiency in Python and familiarity with TensorFlow and/or PyTorch.
- Basic knowledge of neural network architectures and optimization techniques.

IV. Content

Chapter 1: Introduction to Deep Learning

- Overview of deep learning history and key concepts
- Basic structure of neural networks: neurons, layers, and propagation
- Activation functions (ReLU, sigmoid, tanh) and optimization techniques
- Regularization methods (Dropout, Batch Normalization)
- Principles and applications of transfer learning

Chapter 2: Convolutional Neural Networks (CNNs)

- Fundamentals of convolution operations and filters
- Pooling methods (max pooling, average pooling) and feature extraction
- In-depth study of popular CNN architectures (LeNet, AlexNet, VGG, ResNet)
- Best practices for implementing CNNs using TensorFlow/PyTorch

Chapter 3: Autoencoders and Variational Autoencoders (VAEs)

- Introduction to autoencoders and their role in unsupervised learning
- Variational autoencoders: theory and differences from standard autoencoders
- Applications in anomaly detection, image denoising, and representation learning

Labs

- **Lab 1: GPU Environment Setup**
 - Installation and configuration of CUDA/cuDNN
 - Verifying GPU functionality for deep learning tasks
- **Lab 2: CNN Implementation Project**
 - Building a CNN from scratch for image classification (e.g., using MNIST or CIFAR-10)
 - Experimenting with various CNN architectures and hyperparameter tuning
- **Lab 3: Autoencoder and VAE Projects**
 - Implementing a basic autoencoder and visualizing its encoding-decoding process
 - Developing a VAE model to explore latent representations on a sample dataset
- **Lab 4: Supplementary Exercises and Mini-Projects**
 - Debugging and optimizing model performance
 - Collaborative mini-challenges to reinforce theory through practice

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Goodfellow, I., Bengio, Y., & Courville, A. *Deep Learning*. MIT Press, 2016.
2. Nielsen, M., *Neural Networks and Deep Learning*.
3. Chollet, F. *Deep Learning with Python*. Manning Publications, 2018.
4. Stanford University. *CS231n: Convolutional Neural Networks for Visual Recognition*. <https://cs231n.github.io/>
5. Technical University of Munich (TUM). *IN2346: Introduction to Deep Learning*. [TUM Deep Learning Course](#)
6. Géron, A. *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*. O'Reilly Media, 2019.

Teaching Unit	Subject Title	Code	Semester
UET 2.1.1	Antennas and Propagation	APR	S7

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h30	1h00	1h00	3/3

I. Course Objectives

By the end of this course, students will:

- Understand the fundamental principles of antennas and wave propagation.
- Analyze different types of antennas and their radiation characteristics.
- Study the effects of the environment on electromagnetic wave propagation.
- Apply knowledge to the design and selection of antennas for unmanned systems (UAVs, UGVs, and UUVs).
- Conduct practical measurements and simulations of antennas and propagation models.

II. Targeted Skills

Technical Skills

- Understanding antenna characteristics and performance parameters.
- Designing and analyzing different types of antennas.
- Evaluating wave propagation phenomena in different environments.

Analytical Skills

- Applying electromagnetic theory to real-world antenna problems.
- Assessing the impact of terrain, atmosphere, and ionosphere on wave propagation.

Practical Skills

- Performing antenna radiation measurements.
- Using software tools for antenna design and simulation.
- Implementing antenna systems for unmanned vehicles.

III. Recommended Prerequisites

- Basic knowledge of electromagnetism.
- Fundamentals of signal transmission and reception.
- Basic mathematical concepts in calculus and vector analysis.

IV. Course Content

Part I: Antennas

Chapter 1: Introduction to Antennas

- 1.1 Antenna fundamentals and classifications
- 1.2 Key antenna parameters (gain, directivity, efficiency, bandwidth)
- 1.3 Applications in unmanned systems

Chapter 2: Antenna Radiation and Design

- 2.1 Radiation equations and antenna patterns
- 2.2 General theorems (duality, reciprocity, image theorem)
- 2.3 Impedance matching and polarization

Chapter 3: Types of Antennas

- 3.1 Wire antennas (dipoles, monopoles, Yagi antennas)
- 3.2 Loop antennas

- 3.3 Horn antennas and reflector antennas
- 3.4 Printed antennas (microstrip, patch antennas)
- 3.5 Traveling wave antennas and phased arrays

Chapter 4: Antenna Arrays and Coupling

- 4.1 Array factor and beamforming principles
- 4.2 Mutual coupling effects in antenna arrays
- 4.3 Electronic beam scanning and smart antennas

Part II: Wave Propagation

Chapter 5: Free-Space and Ground Wave Propagation

- 5.1 Fundamentals of electromagnetic wave propagation
- 5.2 Free-space wave propagation and Friis transmission equation
- 5.3 Ground wave propagation and terrain influence

Chapter 6: Reflection, Refraction, and Diffraction

- 6.1 Reflection and refraction at dielectric boundaries
- 6.2 Diffraction and scattering effects
- 6.3 Multipath propagation and fading

Chapter 7: Ionospheric and Tropospheric Propagation

- 7.1 Ionospheric layers and their effect on radio waves
- 7.2 Tropospheric refraction and ducting
- 7.3 Atmospheric attenuation and absorption

Chapter 8: Propagation in Complex Environments

- 8.1 Urban and indoor wave propagation
- 8.2 Communication in maritime and underwater environments
- 8.3 UAV communication challenges in various terrains

Part III: Practical Work

1. Measurement of radiation characteristics of horn antennas
2. Analysis of parabolic reflector antennas
3. Printed antennas: design and simulation using CST/HFSS
4. Helical antennas: polarization and performance evaluation
5. Wire antennas: Dipole, Monopole, and Yagi antenna experiments

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. C. A. Balanis, *Antenna Theory: Analysis and Design*, Wiley, 2016.
2. W. L. Stutzman & G. A. Thiele, *Antenna Theory and Design*, Wiley, 2013.
3. R. Aksas, *Antennes: Théorie et conception -Télécommunications*, Ellipses, 2013.
4. R. E. Collin, *Antennas and Radiowave Propagation*, McGraw-Hill, 1985.
5. R. Aksas, *Propagation des ondes électromagnétiques : lois et équations, propagations libre et guidée, cours, exemples et exercices corrigés*, Ellipses, 2021.

Teaching Unit	Subject Title	Code	Semester
UET 2.1.1	Mechanical CAD for Robotics	MCR	S7

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH		2h00	3/3

I. Course Objectives:

By the end of this course, students will:

- Gain proficiency in using SolidWorks for mechanical design.
- Design and model robotic components and assemblies.
- Understand design principles for robotic components (e.g., brackets, gears, chassis).
- Simulate motion and analyze mechanical interactions in assemblies.

II. Targeted Skills:

Upon completing this section, students will have developed the following skills:

- **Technical Skills:**
 - Proficiency in SolidWorks for 3D modeling and assembly design.
 - Ability to simulate and analyze robotic systems.
 - Creating technical drawings and documentation.
- **Analytical Skills:**
 - Solving design problems for robotic components and systems.
 - Evaluating designs for manufacturability and performance.
- **Practical Skills:**
 - Designing and testing robotic components in a virtual environment.
 - Debugging and optimizing mechanical designs.

III. Recommended Prerequisites:

To succeed in this course, students should have:

- Basic knowledge of mechanical engineering concepts.
- Familiarity with 2D and 3D geometry.
- No prior CAD experience required.
- Basic understanding of robotics concepts (e.g., motors, joints, frames) is helpful but not mandatory.

IV. Content:

This course introduces students to the fundamentals of Computer-Aided Design (CAD) using SolidWorks, with a focus on designing components and assemblies for robotics applications. Through a series of guided labs, students will learn how to create 3D models, assemble parts, and simulate motion, all while applying these skills to real-world robotics projects.

Topics:

Chapter 1: Introduction to SolidWorks and CAD Basics

- Overview of the SolidWorks interface.
- Basic sketching tools (lines, rectangles, circles, dimensions).
- Creating a simple 2D sketch.
- Project: Design a robotic base plate.

Chapter 2: Basic 3D Modeling

- Basic 3D modeling: extrusions, revolves, and cuts.
- Using fillets and chamfers.
- Project: Design a simple motor mount.

Chapter 3: Advanced Part Design

- Using patterns (linear and circular).
- Creating holes and threads.
- Project: Design a gear or pulley.

Chapter 4: Assemblies

- Introduction to assemblies.
- Inserting and mating parts (coincident, concentric, distance).
- Project: Assemble a simple robotic arm with two joints.

Chapter 5: Design for Robotics

- Designing brackets and frames.
- Understanding tolerances and clearances.
- Project: Design a chassis for a mobile robot.

Chapter 6: Motion Simulation

- Introduction to motion studies.
- Simulating rotation and translation.
- Project : Simulate the movement of a robotic arm.

Chapter 7: Advanced Assemblies

- Using sub-assemblies.
- Creating exploded views.
- Project: Assemble a multi-jointed robotic arm with gripper.

Chapter 8: Final Project

- Design a complete robotic system (e.g., mobile robot, robotic arm, or drone frame).
- Export files for 3D printing or manufacturing.
- Present the design to the class.

Labs and Projects:

Hands-on labs using SolidWorks to design and model robotic components and systems. Students will complete a final project where they design a complete robotic system.

Evaluation Method

- Module average = 40% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. "SolidWorks for Beginners" by Matt Lombard.
2. "Engineering Design with SolidWorks" by David Planchard.

Teaching Unit	Subject Title	Code	Semester
UED2.1.2	Capstone Project II	CP-II	S7

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH		1h00	2/2

I. Course Objectives

- Develop an initial prototype.
- Conduct iterative testing and debugging.
- Perform a mid-project review.

II. Targeted Skills

- Hands-on prototype development.
- Software/hardware debugging.
- Performance evaluation and improvement.

III. Recommended prerequisites

- Embedded systems and control.
- Prototyping tools and software.
- Testing methodologies.

IV. Content

1. Prototype Development

- Hardware and software integration.
- Initial assembly and testing.

2. Iterative Testing and Debugging

- Identifying and resolving system issues.
- Performance tuning and optimization.

3. Mid-Project Review and Demonstration

- Presenting progress to faculty.
- Gathering feedback and making improvements.

Evaluation Method

- Module average = 100% continuous assessment
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

- Rapid Prototyping: Principles and Applications by Chua C.K.
- Debugging: The 9 Indispensable Rules for Finding Even the Most Elusive Software and Hardware Problems by David Agans

Teaching Unit	Subject Title	Code	Semester
UED2.1.2	Project Management for Engineers	PME	S7

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00			2/2

I. Course Objectives

By the end of this course, students will:

- Understand the fundamentals of project management in an engineering context.
- Learn project planning, execution, and control techniques.
- Develop skills for managing resources, risks, and timelines effectively.
- Apply project management tools and methodologies to engineering projects.
- Gain knowledge of industry standards and best practices in project management.

II. Targeted Skills

Technical Skills

- Project planning and scheduling using tools like Gantt charts and PERT diagrams.
- Resource allocation and budget management.
- Risk assessment and mitigation strategies.

Analytical Skills

- Critical thinking for problem-solving in project execution.
- Decision-making under constraints.
- Performance evaluation and continuous improvement.

Practical Skills

- Team coordination and leadership in engineering projects.
- Using project management software (e.g., Microsoft Project, Trello, or Jira).
- Effective communication and reporting in technical environments.

III. Recommended Prior Knowledge

- Basic understanding of engineering processes.
- Familiarity with technical documentation and reporting.
- Basic knowledge of organizational and business principles.

IV. Course Content

Chapter 1: Introduction to Project Management

- 1.1 Definition and importance of project management in engineering.
- 1.2 Project lifecycle: Initiation, Planning, Execution, Monitoring, and Closure.
- 1.3 Key stakeholders and roles in a project.

Chapter 2: Project Planning and Scheduling

- 2.1 Work Breakdown Structure (WBS) and task dependencies.
- 2.2 Scheduling techniques: Gantt charts, Critical Path Method (CPM), and PERT.
- 2.3 Resource allocation and budget estimation.

Chapter 3: Risk Management and Quality Control

- 3.1 Identifying and assessing risks in engineering projects.
- 3.2 Risk mitigation strategies.
- 3.3 Quality assurance and control techniques.

Chapter 4: Execution, Monitoring, and Control

- 4.1 Project tracking and performance evaluation.
- 4.2 Handling project changes and challenges.
- 4.3 Communication and documentation in project management.

Chapter 5: Case Studies and Best Practices

- 5.1 Engineering project success and failure analysis.
- 5.2 Lessons learned and continuous improvement.
- 5.3 Agile methodologies in engineering project management.

Evaluation Method

- Module average = 40% continuous assessment + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Harold Kerzner, *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, Wiley, 2017.
2. Erik W. Larson & Clifford F. Gray, *Project Management: The Managerial Process*, McGraw-Hill, 2020.
3. PMI, *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*, Project Management Institute, 2021.
4. F. L. Harrison & Dennis Lock, *Advanced Project Management: A Structured Approach*, Routledge, 2017.
5. Bent Flyvbjerg, *How Big Things Get Done*, Currency, 2023.

Detailed programs for the eighth semester

Teaching Unit	Subject Title	Code	Semester
UEF2.2.1	Nonlinear Control Systems	NCS	S8

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h00	1h00	3/3

I. Course Objectives:

By the end of this course, students will:

- Understand the challenges nonlinear systems.
- Analyze stability and behavior of nonlinear systems.
- Design and implement nonlinear control and optimal strategies.

II. Targeted Skills:

Upon completing this course, students will have developed the following skills:

- Technical Skills:
 - Analyzing and controlling nonlinear systems.
 - Implementing advanced and optimal control techniques.
- Analytical Skills:
 - Solving complex nonlinear control problems.
- Practical Skills:
 - Using MATLAB/Simulink for nonlinear system simulation.

III. Recommended prerequisites / Prerequisites:

- Completion of Continuous and Discrete-Time Control Systems.
- Strong mathematical background (calculus, linear algebra, differential equations).

IV. Content:

This course explores the analysis and control of nonlinear systems, which are prevalent in real-world applications.

Topics:

Chapter1: Mathematical Modeling of NL systems

- Nonlinear state space model.
- Existence conditions of the solution
- Tangent linear model and 1st Lyapunov theorem

Chapter2: 2nd order Lyapunov Method

- Lyapunov function .
- 2nd Lyapunov theorem and equilibrium stability analysis
- Lassale/Barbalat extensions.

Chapter3: Nonlinear Control Techniques

- Feedback linearization.
- Sliding mode control.
- Backstepping and Forwarding control.

Chapter4: Adaptive Control

- Indirect Adaptive Control
- Direct Adaptive Control
- Adaptive Model reference control.

Chapter5: Fuzzy modeling and Control

- Fuzzy sets and fuzzy numbers.
- Fuzzy inference systems
- Mamdani Fuzzy controller
- TSK models and control design

Chapter6: Neural Network modeling and Control

- Neural Network approximation and control
- Adaptive Neuro Fuzzy Inference System (ANFIS) control.
- Applications in control and robotics.

Laboratory Work

Lab 1: Control of NL Systems using 1st Lyapunov method

Lab 2: Control of NL Systems using 2nd Lyapunov method

Lab 3: Sliding Mode Control (SMC) and adaptive control

Lab 4: TSK based Fuzzy control for NL systems

Lab 5: ANFIS based control for NL systems

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. H. Khalil – Nonlinear Systems (Prentice Hall, 3rd Edition, 2002)
2. J. Slotine & W. Li – Applied Nonlinear Control (Prentice Hall, 1991)
3. M. Krstic, I. Kanellakopoulos, P. V. Kokotovic – Non linear and Adaptive Control (Wiley-Interscience, 1996)
4. G. Chen, T. T. Pham– Introduction to fuzzy sets, fuzzy logic and fuzzy control systems (CRC Press, 2019)

Teaching Unit	Subject Title	Code	Semester
UEF2.2.1	Optimal Control	OC	S8

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h00	1h00	3/3

I. Course Objectives:

By the end of this course, students will:

- Understand the principles of optimal control.
- Design and implement LQR and MPC controllers.
- Apply optimal control techniques to real-world problems.

II. Targeted Skills:

Upon completing this section, students will have developed the following skills:

- **Technical Skills:**
 - Designing and implementing optimal controllers.
 - Solving optimization problems in control systems.
- **Analytical Skills:**
 - Evaluating and optimizing system performance.
- **Practical Skills:**
 - Using MATLAB for optimal control design and simulation.

III. Recommended Prerequisites:

- Completion of Continuous, Discrete-Time, and Nonlinear Control Systems.
- Strong mathematical background (calculus, optimization).

IV. Content:

This course covers the theory and application of optimal control, focusing on minimizing cost functions and optimizing system performance.

Topics:

Chapter1 : Introduction to Optimal Control

- Problem formulation and cost functions.
- Applications in engineering and economics.

Chapter2 : Calculus of Variations

- Euler-Lagrange equation.
- Hamilton-Jacobi-Bellman equation.

Chapter3 : Linear Quadratic Regulator (LQR)

- Design and implementation.

- Applications in state feedback control.

Chapter4 : Dynamic Programming

- Principle of optimality.
- Applications in control and robotics.

Chapter5 : Model Predictive Control (MPC)

- Principles and implementation.
- Linear MPC
- Non linear MPC (NMPC)
- Applications in process control and robotics.

Laboratory Work

Lab 1: Control of NL Systems using LQ method

Lab 2: Minimum time control

Lab 3: Minimum energy control of Planner UAV

Lab 4: Model Predictive Control for NL systems

Lab 5: NMPC control for NL systems

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. D. Liberzon – Calculus of Variations and Optimal Control Theory (Princeton University Press, 2011)
2. E. F. Camacho & C. Bordons – Model Predictive Control (Springer, 2nd Edition, 2007)
3. B. D. O. Anderson & J. B. Moore – Optimal Control: Linear Quadratic Methods (Dover, 2007)

Teaching Unit	Subject Title	Code	Semester
UEF2.2.2	Advanced AI Techniques	AAT	S8

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h30		2h00	3/3

I. Course Objectives

- Explore advanced neural network architectures and state-of-the-art AI methodologies.
- Understand Bayesian Neural Networks (BNNs) and their applications in uncertainty estimation.
- Dive into auto encoders, variational auto encoders, and generative models like GANs and diffusion models.
- Master Transfer Learning and Object Detection architectures like YOLO and Region-Based CNNs.
- Understand Transformers and Large Language Models (LLMs)
- Develop expertise in contrastive learning and self-supervised learning strategies for diverse applications.

II. Targeted Skills

- Ability to implement and fine-tune BNNs, VAEs, GANs, and transformers.
- Proficiency in transfer learning and object detection techniques.
- Understand cutting-edge AI techniques and their applications.
- Explore open problems in AI, such as uncertainty estimation and generative modeling.
- Deploy advanced AI models in real-world scenarios, ensuring robustness and reliability.

III. Recommended Prerequisites

- Completion of Course Neural Networks and Deep Learning.
- Basic knowledge of probability and statistics.
- Strong understanding of neural networks, CNNs, and RNNs.
- Proficiency in Python and familiarity with machine learning frameworks (TensorFlow, PyTorch).

IV. Content

Chapter 1: Bayesian Neural Networks (BNNs)

- Introduction to Bayesian Inference
 - Basics of probability theory: priors, likelihoods, and posteriors.
 - Bayesian vs. frequentist approaches in machine learning.

- Bayesian Neural Networks
 - Probabilistic interpretation of neural networks.
 - Uncertainty estimation in predictions.
- Training BNNs
 - Variational inference and Monte Carlo methods.
 - Dropout as a Bayesian approximation.
- Applications of BNNs
 - Robust decision-making under uncertainty.
 - Case studies in autonomous systems.

Chapter 2: Auto encoders and Representation Learning

- Introduction to Auto encoders
 - Encoder-decoder architecture and latent space representation.
 - Applications in dimensionality reduction, denoising, and anomaly detection.
- Variational Auto encoders (VAEs)
 - Probabilistic interpretation and KL divergence.
 - Applications in generative modeling and representation learning.
- Advanced Auto encoder Variants
 - Sparse auto encoders, denoising auto encoders, and convolutional auto encoders.
 - Case studies in image generation and feature extraction.

Chapter 3: Generative Learning

- Generative Adversarial Networks (GANs)
 - Architecture, training dynamics, and challenges.
 - Applications in image synthesis, style transfer, and data augmentation.
- Diffusion Models
 - Principles and applications in generative AI.
 - Comparison with GANs and VAEs.

Chapter 4: Transfer Learning for Object Detection

- Fundamentals of Transfer Learning
 - Pre-trained models and fine-tuning strategies.
 - Domain adaptation and generalization.
- Applications in Computer Vision
 - Using pre-trained CNNs (e.g., ResNet, VGG) for transfer learning.
 - Case studies in medical imaging, satellite imagery, and more.
- Object Detection Architectures
 - YOLO (You Only Look Once):
 - Region-Based CNNs: R-CNN, Fast R-CNN, Faster R-CNN, and Mask R-CNN.

Chapter 5: Transformers and Attention Mechanisms

- Transformer-Based Architectures
 - Self-attention mechanism and multi-head attention.
 - Encoder-decoder architecture and its applications.
- Applications in Vision and NLP
 - Vision Transformers (ViTs) for image classification.
 - Transformers in natural language processing (e.g., BERT, GPT).

Chapter 6: Large Language Models (LLMs)

- Architectural Overview of LLMs
 - BERT, GPT, T5, and their variants.
 - Scaling laws and model size trends.
- Fine-Tuning Pre-Trained LLMs
 - Techniques for domain-specific adaptation.
 - Prompt engineering and few-shot learning.

Labs:

Lab 1: Bayesian Neural Networks (BNNs).

Lab 2: Autoencoders and Variational Autoencoders (VAEs).

Lab 3: Generative Adversarial Networks (GANs).

Lab 4: Transfer Learning: Training and testing YOLO and R-CNN models.

Lab 5: Transformers and Large Language Models (LLMs).

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Goodfellow, I., Bengio, Y., & Courville, A. Deep Learning. MIT Press, 2016.
2. Murphy, K., • Probabilistic Machine Learning: Advanced Topics.
3. OpenAI Blog and Research Papers on Large Language Models.
4. Géron, A. *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow*. O'Reilly Media, 2019.
5. Stanford University. *CS231n: Convolutional Neural Networks for Visual Recognition*. <https://cs231n.github.io/>

Teaching Unit	Subject Title	Code	Semester
UEF2.2.2	Advanced Navigation Systems	ANS	S8

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	3/3

I. Course Objectives:

By the end of this course, students will:

- Understand and implement advanced SLAM techniques, including EKF-SLAM.
- Develop and evaluate advanced path planning algorithms.
- Apply dynamic obstacle avoidance techniques in real-world scenarios.
- Gain expertise in multi-sensor fusion for robust perception.
- Analyze and solve challenges in complex autonomous navigation tasks, including unstructured, dynamic environments.
- Design and deploy autonomous navigation systems in real-world applications, such as autonomous vehicles, drones, and mobile robots.

II. Targeted Skills:

Upon completing this section, students will have developed the following skills:

- **Technical Skills:**
 - Advanced proficiency in ROS2 for complex robotics tasks.
 - Ability to implement and optimize SLAM algorithms.
 - Expertise in advanced path planning and obstacle avoidance.
- **Analytical Skills:**
 - Solving complex navigation problems in cultured environments.
 - Evaluating and improving algorithm performance.
- **Practical Skills:**
 - Hands-on experience with advanced robotics simulation and testing.
 - Ability to design and test autonomous systems in real-world experimentation.

III. Recommended prerequisites:

- Completion of basics of Autonomous Navigation or equivalent knowledge.
- Strong programming skills in Python or C++.
- Familiarity with ROS2 and basic robotics concepts.

IV. Content:

This course builds on the foundational knowledge from basics of Autonomous Navigation and delves into advanced topics such as SLAM, advanced path planning, and dynamic obstacle avoidance. Students will further develop their skills in ROS2 and apply advanced techniques to complex navigation problems.

Topics:

Chapter 1: Localization Techniques

- A Taxonomy of Localization Problems.
- EKF Localization.
- Grid Localization.
- Monte Carlo Localization (MCL).
- Localization in Dynamic Environments.

Chapter 2: Simultaneous Localization and Mapping

- Occupancy Grid Mapping.
- Data Association and Map Building Algorithms.
- SLAM Principles and Algorithms: EKF-SLAM, Graph-SLAM, and modern approaches (e.g., ORB-SLAM, LIO-SAM).
- Challenges in SLAM: Scalability, robustness, and handling dynamic environments.

Chapter 3: Path Planning

- Graph search methods: A*, Dijkstra, and their variants.
- Sampling-based planning: Rapidly-exploring Random Trees (RRT), RRT*.
- Heuristic and informed search methods.

Chapter 4: Obstacle Avoidance

- Potential Field Methods: Theory, implementation, and limitations.
- Dynamic Window Approach (DWA): Principles, tuning, and integration with path planning.
- Integration with Path Planning: Balancing global and local planning.

Chapter 5: Dynamic Obstacle Tracking and Avoidance

- Bayesian Filtering for Object Tracking: Kalman filters, particle filters, and multi-object tracking.
- Dynamic Obstacle Avoidance: Predictive collision avoidance and risk-aware planning.
- Integration with Navigation Systems: Real-time decision-making in dynamic environments.

Chapter 6: Control Strategies for Navigation

- Trajectory tracking and path following.
- Model predictive control (MPC) for dynamic obstacle avoidance.

Chapter 7: Machine Learning-Based Navigation

- Learning-Based Perception: Deep learning for object detection, segmentation, and tracking.
- Learning-Based Planning: Reinforcement learning for path planning and obstacle avoidance.
- End-to-End Navigation Systems: Challenges and opportunities.

Chapter 8: Real-World Applications and Challenges

- Case studies of autonomous navigation in complex environments.
- Challenges in dynamic and unstructured environments
- Ethical and Legal Considerations: Privacy, safety, and regulatory compliance.

Chapter 9: Global navigation satellite systems

- Introduction to Global Navigation Satellite System (GNSS)

- GPS
- BeiDou Navigation Satellite System (BDS)
- Indian Regional Navigation Satellite System (IRNSS)
- GALILEO
- Quasi-Zenith Satellite System (QZSS)
- GNSS Errors
- GNSS Correction Methods

Labs:

All labs will be implemented using ROS2, focusing on advanced algorithms and real-world applications.

Lab1: Implementing and testing a Localization technique with ROS2

Lab2: Implementing and testing SLAM with ROS2

Lab3: Path planning in cluttered environment.

Lab4: Dynamic Obstacle Tracking.

Lab5: Autonomous navigation in dynamic obstacles.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Siegwart, R., Nourbakhsh, I.R., & Scaramuzza, D. (2011). *Introduction to Autonomous Mobile Robots*. MIT Press.
2. Thrun, S., Burgard, W., & Fox, D. (2005). *Probabilistic Robotics*. MIT Press.
3. LaValle, S.M. (2006). *Planning Algorithms*. Cambridge University Press.
4. Grewal, M. S., Andrews, A. P. "Kalman Filtering: Theory and Practice." Wiley, 2015.
5. Official ROS and SLAM Toolbox Documentation.
6. Hofmann-Wellenhof, B., Lichtenegger, H., Wasle, E., 2008. *GNSS – Global Navigation Satellite Systems*, Springer, Verlag Wien.
7. Hofmann-Wellenhof, B., Lichtenegger, H., Collins, J., 2001. *Global Positioning System Theory and Practice*, Springer, Verlag Wien.
8. Tan, S., 2018. *GNSS Systems and Engineering: The Chinese Beidou Navigation and Position Location Satellite*, JohnWiley & Sons, Singapore

Teaching Unit	Subject Title	Code	Semester
UEF2.2.2	Aerodynamics and Hydrodynamics	AH	S8

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h00	1h00	3/3

I. Course Objectives

The general objective of this course is to provide students with a comprehensive understanding of the fundamental principles of aerodynamics and hydrodynamics, with a specific focus on their application to autonomous systems, particularly drones. This course is designed to equip students with both the theoretical knowledge and the practical tools necessary to analyze, simulate, and optimize the aerodynamic and hydrodynamic performance of drones.

Through a combination of theoretical learning and hands-on practical experience, students will:

- Understand and apply fundamental aerodynamic and hydrodynamic principles.
- Use advanced simulation tools and techniques: The course will teach students how to apply computational tools, such as Computational Fluid Dynamics (CFD), MSFS (Microsoft Flight Simulator) with FSUIPC integration, and Airwrench, to analyze real-world drone performance.
- Model flight environments using the ISA atmospheric model.
- Conduct aerodynamic identification and performance analysis.
- Evaluate and optimize drone performance for various missions.

II. Targeted Skills

By the end of the course, students will be able to integrate aerodynamic and hydrodynamic principles with state-of-the-art computational techniques, enabling them to design, analyze, and optimize autonomous drones for a wide range of real-world applications and missions.

III. Recommended Prior Knowledge

- Understanding of classical mechanics, including Newton's laws of motion, forces, and energy.
- Familiarity with CAD software (e.g., SolidWorks, Blender) to model drone geometries for simulations.
- Basic knowledge of programming languages (such as Python, MATLAB, or C++) for simulations and data analysis.

IV. Course Content

CHAPTER 1: Introduction to Aerodynamics and Hydrodynamics

- Definitions and basic principles (fluids, flow, etc.).
- Differences between aerodynamics and hydrodynamics.
- Fundamental forces: lift, drag, side force, weight.
- Applications to drones: impact of these forces on stability and performance of flying systems.

CHAPTER 2: Aerodynamic Forces and Their Influence on Drone Performance

- Aerodynamic forces: lift, drag, pitch, roll, and yaw moments.
- Factors influencing these forces: speed, angle of attack, shape of the aircraft.
- Effects of drag and side force on drone performance.
- Using lift and drag theory to design more efficient drones.

CHAPTER 3: Introduction to MSFS for Aerodynamic Performance Simulation

- Introduction to MSFS and its aerodynamic simulation capabilities.
- Creating custom drone models in MSFS.
- Plotting aerodynamic polars to analyze lift and drag under different conditions.
- Using MSFS to simulate specific flight conditions and optimize drone aerodynamic configurations.
- Analyzing results and interpreting aerodynamic polars.

CHAPTER 4: Practical Applications and Case Studies

- Case studies: analyzing aerodynamic performance of a drone based on design (e.g., type of rotors, materials, geometry).
- Comparing different drone models in terms of drag and lift using MSFS simulation results.
- Optimizing aerodynamic performance for specific missions (e.g., surveillance, delivery, reconnaissance).
- Introduction to autonomous flight control principles in relation to aerodynamics.

CHAPTER 5: Hydrodynamics and Its Applications to Underwater Drones

- Hydrodynamic forces: lift and drag underwater
- Comparison between aerodynamics and hydrodynamics in the design of underwater drones
- Case studies on underwater drones and their interaction with aquatic environments.

CHAPTER 6: Introduction to CFD (Computational Fluid Dynamics) and Its Application to Drone Aerodynamics

- Modeling aerodynamic forces on a drone: lift, drag, and ground effect study.
- Simulation of flow around the drone geometry: analyzing flow separation, vortices, and low-pressure areas.
- Using CFD to optimize a drone's shape by reducing drag and increasing lift
- Analyzing the influence of geometric configurations on drone performance.

Laboratory Work**Lab 1 (Environmental Modeling with ISA):**

- Understand the standard atmospheric conditions and their impact on drone performance.
- Simulate altitude profiles to observe variations in temperature, pressure, and density.

Lab 2 (Aerodynamic Identification with RLS and MSFS):

- Identify real-time aerodynamic coefficients using Recursive Least Squares (RLS) with a forgetting factor.
- Use FSUIPC to collect flight data and analyze aerodynamic performance.

Lab 3 (Polars and Performance with Airwrench):

- Use Airwrench to analyze the aerodynamic polars and determine the drone's aerodynamic performance under various flight conditions.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Fundamentals of Aerodynamics by John D. Anderson, Sixth Edition, McGraw Hill, 2016.
2. Introduction to Flight by John D. Anderson, Eighth Edition, McGraw Hill, 2015.
3. Airplane Aerodynamics and Performance, J. Roskam,, Part I, DARcorporation, 2016.

Teaching Unit	Subject Title	Code	Semester
UEM2.2.1	Human-robot interaction	HRI	S8

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00	1h00	1h00	3/3

I. Course Objectives

By the end of this course, students will:

- Understand the principles of human-robot interaction (HRI) and user-centered design for robotic systems.
- Learn how to design, evaluate, and optimize interactions between humans and autonomous robots.
- Analyze human cognitive, social, and physiological factors affecting collaboration with robots.
- Explore multimodal interaction techniques, including speech, gestures, and haptic feedback.
- Implement and test HRI solutions in both physical and simulated environments.

II. Targeted Skills

Technical Skills

- Designing intuitive and adaptive interfaces for human-robot collaboration.
- Implementing multimodal interaction techniques (voice, gestures, touch, and haptics).
- Programming and integrating HRI solutions using software tools (e.g., ROS, Unity, OpenCV).

Analytical Skills

- Evaluating user experience (UX) and system usability in human-robot teamwork.
- Applying cognitive psychology principles to interaction design.
- Analyzing trust, workload, and decision-making in human-robot interactions.

Practical Skills

- Developing interactive prototypes for human-robot collaboration.
- Conducting usability tests and cognitive workload assessments.
- Using physiological sensors (eye-tracking, EEG) to evaluate human response to robots.

III. Recommended Prerequisites

- Basic programming skills (Python, C++, or MATLAB).
- Fundamentals of control systems and robotics.
- Introduction to human factors and ergonomics.
- Basic knowledge of AI and machine learning.

IV. Course Content

Chapter 1: Introduction to Human-Robot Interaction

- 1.1 Definition and importance of HRI.
- 1.2 Evolution of HRI in robotics and automation.
- 1.3 Applications in unmanned aerial, ground, and underwater robots.

Chapter 2: Human Factors in Human-Robot Interaction

- 2.1 Cognitive and perceptual aspects of interaction with robots.
- 2.2 Trust, workload, and situational awareness in robotic systems.
- 2.3 Decision-making and risk perception in human-robot collaboration.

Chapter 3: Designing Interactive Robots

- 3.1 Principles of user-centered robot design.
- 3.2 Visual, auditory, and haptic feedback in HRI.
- 3.3 Adaptive and personalized interaction techniques.

Chapter 4: Communication and Collaboration with Robots

- 4.1 Natural language processing (NLP) for speech interaction.
- 4.2 Gesture and facial recognition for nonverbal communication.
- 4.3 Shared control and assistive robotics for human augmentation.

Chapter 5: Sensor Integration and Feedback Systems

- 5.1 Haptic and force feedback in robotic control.
- 5.2 Eye-tracking and biometric sensing in HRI.
- 5.3 Emotion recognition and affective computing for robots.

Chapter 6: Usability Testing and HRI Performance Evaluation

- 6.1 Metrics for evaluating human-robot collaboration.
- 6.2 Methods: cognitive load measurement, response time, task success rates.
- 6.3 User feedback and iterative improvement in HRI systems.

Chapter 7: Ethical and Social Considerations in HRI

- 7.1 Trust and transparency in robotic decision-making.
- 7.2 Ethical concerns in AI-assisted and autonomous robotic systems.
- 7.3 Designing for inclusivity and accessibility in robotics.

Chapter 8: Case Studies and Emerging Trends in HRI

- 8.1 Human-robot collaboration in industry and healthcare.
- 8.2 Augmented reality (AR) and virtual reality (VR) for HRI.
- 8.3 AI-driven adaptive interfaces for social and service robots.

Laboratory Work

- **Lab 1:** Designing an interactive HRI prototype for robot control
- **Lab 2:** Implementing gesture and voice commands for robot interaction
- **Lab 3:** Measuring user cognitive load and trust in HRI
- **Lab 4:** Integrating haptic feedback in robotic control systems
- **Lab 5:** Conducting a user study on a human-robot teamwork scenario

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. **Goodrich, M. A., & Schultz, A. C.** "Human-Robot Interaction: A Survey." Foundations and Trends in Human-Computer Interaction, 2007.
2. **Norman, D. A.** "The Design of Everyday Things." Basic Books, 2013.
3. **Lee, J. D., & See, K. A.** "Trust in Automation: Designing for Appropriate Reliance." Human Factors, 2004.

4. **Sheridan, T. B.** "Human-Robot Interaction: Status and Challenges." Human Factors, 2016.
5. **Hancock, P. A., Billings, D. R., & Schaefer, K. E.** "Can You Trust Your Robot?" Ergonomics in Design, 2011.

Teaching Unit	Subject Title	Code	Semester
UEM2.2.1	UAV Flight Testing and Operations	UFTO	S8

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH		2h00	3/3

I. Course Objectives

By the end of this course, students will:

- Understand the fundamental principles of UAV flight testing and operations.
- Develop knowledge of pre-flight planning, safety procedures, and regulatory requirements.
- Gain hands-on experience in UAV testing, flight data collection, and performance evaluation.
- Learn how to analyze UAV flight dynamics and troubleshoot operational issues.
- Apply best practices for mission planning and risk management in UAV operations.

II. Targeted Skills

Technical Skills

- Conducting UAV pre-flight inspections and system checks.
- Performing manual and autonomous flight tests.
- Analyzing flight data and sensor logs for performance assessment.
- Understanding emergency procedures and fail-safe mechanisms.

Analytical Skills

- Evaluating UAV stability and control performance.
- Identifying flight anomalies and diagnosing operational issues.
- Applying flight data analysis for improving UAV performance.

Practical Skills

- Executing UAV test flights in different environmental conditions.
- Implementing safety protocols and risk assessments.
- Developing operational workflows for UAV deployment.

III. Recommended Prior Knowledge

- Basics of aerodynamics and flight mechanics.
- Fundamentals of UAV navigation and control.
- Knowledge of UAV regulations and safety protocols.
- Programming experience in UAV-related software (e.g., PX4, ArduPilot, Mission Planner).

IV. Course Content

Chapter 1: Introduction to UAV Flight Testing

- 1.1 Purpose and objectives of UAV flight testing.
- 1.2 Categories of UAV flight tests (performance, endurance, stability).
- 1.3 Overview of flight test instrumentation and data acquisition.

Chapter 2: UAV Pre-Flight Planning and Safety Procedures

- 2.1 UAV airworthiness checks and maintenance.
- 2.2 Pre-flight checklists and system verification.
- 2.3 Risk assessment and emergency handling procedures.

Chapter 3: Flight Testing Techniques and Performance Evaluation

- 3.1 Manual vs. autonomous flight testing.
- 3.2 Evaluating UAV stability, maneuverability, and response.
- 3.3 Data logging and telemetry analysis.

Chapter 4: Environmental Factors and UAV Operations

- 4.1 Effects of wind, temperature, and humidity on UAV performance.
- 4.2 Flight operations in urban vs. rural environments.
- 4.3 Safety considerations for BVLOS (Beyond Visual Line of Sight) operations.

Chapter 5: Flight Data Analysis and Post-Flight Evaluation

- 5.1 Sensor data processing and interpretation.
- 5.2 Identifying anomalies and performance limitations.
- 5.3 Reporting and documenting flight test results.

Chapter 6: UAV Mission Planning and Advanced Operations

- 6.1 Route planning and waypoint navigation.
- 6.2 Payload integration and testing (cameras, LiDAR, sensors).
- 6.3 Operational challenges in different UAV applications (mapping, surveillance, delivery).

Laboratory Work

Lab 1: Pre-Flight Inspections and Ground Tests

Lab 2: Manual and Autonomous Flight Tests

Lab 3: Flight Data Collection and Analysis

Lab 4: Emergency Procedures and Flight Failures

Lab 5: Mission Execution and Performance Assessment

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Austin, R. *Unmanned Aircraft Systems: UAVs Design, Development, and Deployment*, Wiley, 2010.
2. Beard, R., & McLain, T. *Small Unmanned Aircraft: Theory and Practice*, Princeton University Press, 2012.

3. Gati, J. *Flight Testing of Fixed-Wing Aircraft*, AIAA Education Series, 2017.
4. NTSB Reports on UAV Incidents and Accidents (for case studies).
5. ICAO & Local Algerian UAV Regulations and Operational Guidelines.

Teaching Unit	Subject Title	Code	Semester
UEM2.2.1	Propulsion Systems	PRS	S8

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	3h00			3/3

I. Course Objectives

The objective of this course is to provide students with a thorough understanding of the principles and technologies behind propulsion systems used in aerospace applications, particularly in aircraft and spacecraft. The course covers the fundamental theory of propulsion, the different types of propulsion systems (jet engines, turboprops, rockets), and the methods used to analyze and optimize their performance.

II. Targeted Skills

By the end of the course, students will be able to understand the design, operation, and performance characteristics of propulsion systems and apply this knowledge to solve real-world engineering problems in aerospace.

III. Recommended Prior Knowledge

Students entering this course should have a strong foundation in:

- Knowledge of thermodynamics and fluid mechanics.
- Basic understanding of mechanical engineering principles (forces, stress, and material properties).
- Understanding of mathematics, including calculus and differential equations.

IV. Content

CHAPTER 1: Introduction to Propulsion Systems

- Definition and importance of propulsion in aerospace.
- Overview of the different types of propulsion systems: jet engines, turboprops, rockets, and hybrid systems.
- Basic thermodynamics and fluid mechanics in propulsion systems.
- Key performance parameters: thrust, specific fuel consumption, efficiency, and thrust-to-weight ratio.

CHAPTER 2: Thermodynamics of Propulsion

- The laws of thermodynamics applied to propulsion.
- Thermodynamic cycles: Brayton (jet engines), Rankine (turbines), and rocket propulsion cycles.
- Energy conversion in propulsion: from chemical energy to kinetic energy.
- Ideal and real cycles: efficiency limits and losses.

CHAPTER 3: Jet Propulsion (Turbojet and Turbofan Engines)

- Components of a turbojet engine: compressor, combustion chamber, turbine, and nozzle.
- Operating principles of turbojet and turbofan engines.
- Comparison of turbojet vs turbofan performance.
- Performance analysis: thrust, specific fuel consumption, and efficiency.
- Noise reduction and environmental considerations in turbofan engines.

CHAPTER 4: Turboprop and Propeller Systems

- Components and working principles of a turboprop engine.
- Comparison between turboprop and jet engines: efficiency, speed, and range.
- Propeller design and operation: blade design, pitch, and efficiency.
- Performance analysis of turboprop systems: thrust, fuel consumption, and speed.
- Applications of turboprop systems in small aircraft and unmanned aerial vehicles (UAVs).

CHAPTER 5: Propulsion System Components and Design

- Major propulsion components: compressors, turbines, combustion chambers, nozzles, and afterburners.
- Materials used in propulsion components: high-temperature alloys, composites, and cooling technologies.
- Design considerations: material properties, thermal management, and mechanical stresses.
- Failure modes and durability in propulsion systems.

CHAPTER 6: Advanced Propulsion Concepts

- Electric propulsion systems: principles, advantages, and limitations.
- Hybrid propulsion systems: combining jet and electric propulsion.
- Supersonic and hypersonic propulsion technologies.
- The future of propulsion: sustainable aviation, alternative fuels, and noise reduction technologies.

Evaluation Method

- Module average = 40% continuous assessment + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Aircraft Propulsion by Saeed Farokhi, 2nd Edition, Wiley, 2014.
2. Fundamentals of Jet Propulsion with Applications by Ronald D. Flack, Cambridge Aerospace Series, Series Number 17, 2005.
3. Rocket Propulsion Elements by George P. Sutton, Ninth Edition, Wiley, 2016.
4. Online resources: Engineering simulation tools, propulsion system analysis software;

Teaching Unit	Subject Title	Code	Semester
UET 2.2.1	Cybersecurity for Unmanned Systems	CUS	S8

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH 1h00		1h00	3/3

I. Course Objectives

This course provides students with a comprehensive understanding of cybersecurity challenges and techniques specific to unmanned systems. It covers securing communication links, preventing cyber threats, and ensuring system integrity for autonomous platforms. Students will learn practical methods to protect drones, autonomous vehicles, and robotic systems from hacking, data breaches, and cyber-physical attacks.

II. Targeted Skills

- Identify cybersecurity threats in unmanned systems and autonomous platforms.
- Secure communication channels and prevent hacking attempts.
- Implement authentication, encryption, and intrusion detection systems.
- Apply secure boot, firmware protection, and key management techniques.
- Develop strategies for resilience against cyber-physical attacks.
- Conduct penetration testing and vulnerability assessments on unmanned systems.

III. Recommended Prerequisites

- Introduction to Embedded System Security.
- Cryptography.
- Familiarity with Unmanned System Architecture and Network Security.
- Basic Mathematics and Programming Skills.

IV. Content

CHAPTER 1: Cyber Threats and Challenges in Unmanned Systems

- Security vulnerabilities in UAVs, UGVs, and UUVs.
- Case studies of cyberattacks on drones and autonomous platforms.
- Introduction to cybersecurity principles: Confidentiality, integrity, availability.
- Wireless communication security: Wi-Fi, 5G, LoRa, satellite links.

CHAPTER 2: Secure Communication and Data Protection

- Encryption techniques for securing UAV-to-GCS communication.
- Protection of control signals against spoofing and jamming attacks.
- Secure data transmission using TLS, VPNs, and end-to-end encryption.
- Implementing authentication mechanisms (digital signatures, PKI).

CHAPTER 3: Intrusion Detection and System Hardening

- Cybersecurity frameworks for unmanned systems (NIST, ISO 27001).
- Intrusion detection and prevention for real-time autonomous systems.
- Securing onboard processors, flight controllers, and mission computers.

- Firewall configurations and network segmentation for autonomous fleets.

CHAPTER 4: Embedded Security and Firmware Protection

- Secure boot and firmware integrity verification techniques.
- Protection against malware and backdoor vulnerabilities.
- Memory protection mechanisms and stack hardening.
- Preventing reverse engineering and unauthorized firmware modifications.

CHAPTER 5: Cyber-Physical Threats and Future Security Trends

- GPS spoofing and mitigation techniques.
- Quantum-resistant cryptography for unmanned systems.
- AI-driven threat detection and response.
- Case study: Cyber incidents in autonomous defense and commercial UAVs.

Lab Work

- **Lab 1:** Penetration testing of an unmanned aerial system (UAS).
- **Lab 2:** Secure communication implementation for drone telemetry.
- **Lab 3:** Real-time intrusion detection on an autonomous vehicle.
- **Lab 4:** Encryption and authentication for mission-critical data.
- **Lab 5:** Securing GPS and navigation systems against spoofing.
- **Lab 6:** Incident response and forensic analysis of a cyberattack on a robotic system.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Goldsmith, A. "Wireless Communications." Cambridge University Press, 2005.
2. Stallings, W. "Cryptography and Network Security: Principles and Practice." Pearson, 2017.
3. Tyson Macaulay, Bryan L. Singer. "Cybersecurity for Industrial Control Systems: SCADA, DCS, PLC, HMI, and SIS." CRC Press, 2012.
4. Craig, A. "Cybersecurity for Unmanned Systems: Securing the Future of Autonomous Technology." Wiley, 2021.
5. IEEE Standards Association. "Cybersecurity Standards for Autonomous Systems and IoT Security." IEEE Press, 2020.

Teaching Unit (UF)	Subject Title	Code	Semester
UED2.2.1	Reverse Engineering and Rapid Prototyping	RERP	S8

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h30			1/1

Course Overview:

This course introduces students to the principles, techniques, and practices of reverse engineering and rapid prototyping. It covers methods for digitizing physical objects, reconstructing 3D models, and fabricating prototypes using additive and subtractive manufacturing techniques. Students will learn how to analyze existing products, extract design information, and use this data to create new prototypes quickly and efficiently. The course emphasizes the integration of CAD, scanning technologies, and advanced manufacturing for industrial applications.

Course Objectives:

By the end of this course, students will be able to:

1. Understand the fundamentals of reverse engineering and rapid prototyping.
2. Use 3D scanning and data acquisition techniques.
3. Process and reconstruct 3D models from scanned data.
4. Apply additive and subtractive manufacturing technologies for prototyping.
5. Assess the advantages and limitations of different RP technologies.
6. Implement reverse engineering and RP techniques in real-world applications.

Prerequisites:

- Basics of Mechanical Design and Manufacturing
- CAD (Computer-Aided Design) Fundamentals
- Knowledge of Materials and Manufacturing Processes
- Basic Programming (Python, MATLAB, or similar)

Course outline:

Chapter 1: Introduction to Reverse Engineering & Rapid Prototyping

- Definition, scope, and importance of Reverse Engineering (RE) & Rapid Prototyping
- Historical context and modern applications
- Industrial applications
- Relationship with CAD , digital manufacturing, Product Development and Innovation

Chapter 2: Reverse Engineering Process

- Steps in Reverse Engineering
- Object digitization techniques
- 3D scanning technologies (Laser scanning, Structured light, CT scanning)
- Point cloud processing and surface reconstruction

Chapter 3: CAD Modeling for Reverse Engineering

- Introduction to CAD software (e.g., SolidWorks, Fusion 360).
- Converting Scan Data into CAD Models

- Surface Reconstruction and Mesh Processing
- Parametric and Non-Parametric Modeling
- File Formats and Data Conversion (STL, IGES, STEP, ...)
- Error correction and model optimization

Chapter 4: Additive Manufacturing (AM) Technologies

- Overview of 3D printing technologies:
 - Fused Deposition Modeling (FDM)
 - Stereolithography (SLA)
 - Selective Laser Sintering (SLS)
 - Digital Light Processing (DLP)
 - Direct Metal Laser Sintering (DMLS)
- Material considerations: plastics, metals, ceramics, and composites

Chapter 5: Subtractive Manufacturing and Hybrid Techniques

- CNC machining for prototyping
- Laser cutting and engraving
- Hybrid manufacturing: combining additive and subtractive techniques

Chapter 6: Design for Additive Manufacturing (DfAM)

- From 3D Scanning to 3D Printing
- Design constraints and optimization
- Lattice structures and topology optimization
- Post-processing and finishing techniques

Chapter 7: Applications and Case Studies

- Aerospace, automotive, biomedical, and consumer products
- Customization and personalization of products.
- Rapid tooling and manufacturing.
- Legal and ethical considerations in reverse engineering
- Future trends in rapid prototyping and reverse engineering

Assessment Methods:

- Final exam (100%).

Recommended Textbooks and Resources:

1. **Gibson, I., Rosen, D.W., Stucker, B.** (2015). *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing*. Springer.
2. **Varady, T., Martin, R.R., Cox, J.** (1997). *Reverse engineering of geometric models – An introduction*. Computer-Aided Design.
3. **Rafiq Noorani (2005)** "Rapid Prototyping: Principles and Applications" ISBN: 978-0-471-73001-9
4. **Software manuals:** Geomagic, SolidWorks, Fusion 360, Cura, etc.

Teaching Unit	Subject Title	Code	Semester
UED 2.2.1	Capstone Project III	CP-III	S8

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH		2h00	1/1

I. Course Objectives

- Finalize the prototype.
- Conduct the final demonstration and evaluation.
- Prepare a comprehensive project report.

II. Targeted Skills

- Advanced debugging and optimization.
- Technical documentation.
- Public presentation skills.

III. Recommended prerequisites

- Advanced system testing.
- Industry-standard reporting methods.

IV. Content

1. **Refining the Prototype**
 - Performance validation and stress testing.
 - Enhancing system reliability.
2. **Final Demonstration and Evaluation**
 - Faculty and industry expert evaluation.
 - Addressing last-minute issues.
3. **Comprehensive Project Report and Publication**
 - Preparing final documentation.
 - Exploring publication and patent possibilities.

Evaluation Method

- Module average = 100% continuous assessment
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

- Technical Writing for Engineers & Scientists by Leo Finkelstein
- The Art of Public Speaking by Stephen E. Lucas

Teaching Unit	Subject Title	Code	Semester
UED 2.2.1	Training Internship II	TI-II	S8

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH			1/1

I. Course Objectives

- Strengthen practical skills through deeper industry engagement.
- Apply theoretical knowledge to real-world problems.
- Develop problem-solving and critical thinking abilities.

II. Targeted Skills

- Advanced technical proficiency.
- Independent problem-solving.
- Effective collaboration in teams.
- Adaptation to professional expectations.

III. Recommended prerequisites

- Intermediate knowledge of unmanned systems and navigation.
- Hands-on experience with basic tools and technologies.

IV. Content

1. Company Integration

- Reviewing company expectations and past experience.
- Workplace protocols and project assignments.

2. Active Participation in Projects

- Engaging in specific technical tasks.
- Working alongside professionals in real-world scenarios.

3. Reporting and Documentation

- Documenting progress and key learnings.
- Mid-internship feedback session.

4. Final Assessment and Report Submission

- Presenting internship experience to faculty.
- Final evaluation by company mentor.

Evaluation Method

- Module average = 100% continuous assessment
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

- The Successful Internship by H. Frederick Sweitzer
- Problem Solving 101: A Simple Book for Smart People by Ken Watanabe

Detailed programs for the ninth semester

Teaching Unit	Subject Title	Code	Semester
UEF3.1.1	Advanced UAS Programming	AUP	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00	1h00	2h00	4/4

I. Course Objectives

- Master Advanced Programming Concepts: Understand and implement advanced software architectures and programming paradigms for Unmanned Aircraft Systems (UAS).
- Develop Real-Time and Embedded Applications: Gain expertise in real-time operating systems, embedded programming, and fault-tolerant software design critical for high-performance unmanned systems.
- Integrate Sensor and Data Fusion Algorithms: Learn to integrate and program sensor fusion, state estimation, and SLAM techniques into UAS for robust navigation and control.
- Advance Autonomy and Mission Planning: Design and implement autonomy algorithms including mission planning, dynamic obstacle avoidance, and AI-driven decision-making.
- Utilize Simulation and Testing Tools: Develop skills in simulation environments, software-in-the-loop (SIL) and hardware-in-the-loop (HIL) testing to validate advanced UAS software.

II. Targeted Skills

- Software Architecture & Design: Ability to design scalable, modular, and fault-tolerant software systems.
- Real-Time and Embedded Programming: Proficiency in real-time programming, scheduling, and embedded systems development.
- Sensor Integration & Data Processing: Expertise in programming sensor fusion algorithms, state estimation (e.g., Kalman filters), and SLAM.
- Autonomous Navigation & Mission Planning: Competence in developing advanced navigation, path planning, and dynamic obstacle avoidance strategies.
- Simulation and Testing: Skills in utilizing simulation tools and conducting SIL/HIL testing for performance validation.

III. Recommended Prerequisites

Students entering this course should have a strong foundation in:

- Core UAS and Robotics Concepts: Familiarity with advanced robotics programming, as developed in previous courses and projects.
- Control Systems and Navigation: Basic knowledge of control theory and previous experience with autonomous navigation algorithms.
- Programming and Embedded Systems: Proficiency in programming languages such as C/C++, Python, or similar; and an understanding of embedded system design.
- Sensor Technologies and Data Fusion: Experience with integrating sensor data (e.g., from GPS, IMU, cameras) and applying basic data fusion techniques.
- Real-Time Operating Systems: An introductory background in real-time systems and their application in robotics and UAS.

IV. Content

Chapter 1: Introduction to Advanced UAS Programming

- 1.1. Overview of Advanced UAS Systems and Architectures
- 1.2. UAS Software Architecture and Middleware
- 1.3. Software Design Principles for Unmanned Systems

Chapter 2: Autopilot Architecture

- 1.1. Autopilot Hardware and software architecture
- 1.2. Embedded Programming Techniques
- 1.3. Popular open source software autopilot (PX4, APM, etc.)

Chapter 3: Autonomy, Mission Planning, and Control

- 1.1. Advanced Navigation and Autonomy Algorithms
- 1.2. Mission Planning and Path Optimization
- 1.3. Obstacle Avoidance and Dynamic Replanning
- 1.4. Integration of AI and Machine Learning in UAS

Chapter 4: Ground Station & UI Programming

- 1.1. Creating simple GCS tools (e.g., with PyQt or ROS + RViz)
- 1.2. Visualizing telemetry data
- 1.3. Sending mission commands from a GUI
- 1.4. Debugging and Performance Analysis Tools for UAS Programming

Chapter 5: Computer Vision & Payload Programming

- 1.1. Basics of vision pipelines for drones (OpenCV, YOLO, ArUco)
- 1.2. Payload control (gimbals, cameras)
- 1.3. Target tracking, landing pad detection
- 1.4. Integration with onboard compute (Jetson Nano, Pi)

Chapter 6: Simulation & Hardware-in-the-Loop (HIL/SIL)

- 1.1. Gazebo or jMAVSim with PX4
- 1.2. SITL/HIL setup for testing custom code
- 1.3. Continuous integration for UAS code

Chapter 7: Case Studies and Future Trends in UAS Programming

- 1.1. Case Studies in Advanced UAS Software
- 1.2. Emerging Technologies and Future Directions

Laboratory Work

Lab 1: Programming a basic flight controller within a simulated environment.

Lab 2: Implementation of SLAM and Mapping Algorithms.

Lab 3: Mission planning and dynamic obstacle avoidance algorithm development in simulation.

Lab 4: Implementation of a UAS mission (surveillance, agriculture) within a simulated environment.

Lab 5: Integration testing using software-in-the-loop and hardware-in-the-loop (SIL/HIL) simulations.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam

- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Austin, R. (2010). *Unmanned Aircraft Systems: The Definitive Guide*. A comprehensive resource covering the design and programming of UAS.
2. Fahlstrom, P. G. & Gleason, T. J. (2007). *Introduction to UAV Systems*. A foundational text for understanding the systems and software that power UAVs.
3. Beard, R. W. & McLain, T. W. (2012). *Small Unmanned Aircraft: Theory and Practice*. Explores practical aspects of UAS design and autonomous control.
4. Laplante, P. A. (2004). *Real-Time Systems Design and Analysis*. Provides insights into real-time operating systems and embedded programming relevant to UAS.
5. Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D. (2011). *Introduction to Autonomous Mobile Robots*. Although broader in scope, this book offers valuable background on autonomy and navigation algorithms.

Teaching Unit	Subject Title	Code	Semester
UEF3.1.1	Fundamentals of Aerospace Engineering	FAE	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	3h00			4/4

I. Course Objectives

The objective of this module is to introduce students to the fundamental principles of aerospace engineering, covering the essential concepts required to understand the design, analysis, and operation of aerospace systems. The course will provide a solid foundation in key areas such as aerodynamics, materials, structures, and systems engineering, with a focus on both theoretical principles and their practical applications in the aerospace industry. By the end of the module, students will be prepared to tackle more advanced topics in aerospace engineering and contribute to the design and development of aerospace systems.

II. Targeted Skills

By the end of this module, students will be able to:

- **Understand the fundamental principles of aerospace engineering**, including aerodynamics, materials, structures, and systems engineering.
- **Apply theoretical principles** to analyze and solve practical problems in aerospace design and performance.
- **Use basic engineering tools and methods** for aerodynamic and structural analysis.
- **Work effectively in teams** to design and optimize aerospace systems, taking into account the integration of various subsystems.
- **Evaluate and select appropriate materials and components** for aerospace applications based on performance, cost, and safety requirements.
- **Understand the role of control systems** in maintaining stability and performance in aerospace vehicles.

III. Recommended Prior Knowledge

Students entering this course should have a strong foundation in:

- Basic knowledge of physics, particularly mechanics and thermodynamics.
- Understanding of mathematics (calculus and differential equations).
- Basic familiarity with engineering principles and problem-solving techniques.

IV. Content

CHAPTER 1: Introduction to Aerospace Engineering

- History and evolution of aerospace engineering.
- Key milestones in aviation and space exploration.
- Overview of the aerospace industry: commercial, military, and space applications.
- Fundamental challenges and innovations in aerospace engineering.

CHAPTER 2: Principles of Aerodynamics

- Overview of fluid mechanics and aerodynamics.
- Basic aerodynamic forces: lift, drag, thrust, and weight.
- Bernoulli's principle and airflow over airfoils.
- Aerodynamic coefficients: lift, drag, and moment.
- Flow types: subsonic, transonic, supersonic, and hypersonic.
- Airfoil design and analysis.

CHAPTER 4: Aerospace Materials

- Properties of aerospace materials: strength, weight, fatigue resistance, and temperature tolerance.
- Metals, composites, and advanced materials in aerospace applications.
- Material selection for structural and thermal requirements.
- Introduction to material testing and failure modes.
- Practical Application: Case studies on material selection for different aerospace components.

CHAPTER 5: Aircraft and Spacecraft Structures

- Basic principles of structural analysis in aerospace.
- Types of structural components: fuselage, wings, empennage, and landing gear.
- Loads and stresses acting on aerospace structures.
- Structural design considerations: weight, strength, and fatigue.
- Introduction to stress and strain analysis for aerospace components.
- Practical Application: Simple structural analysis for an aircraft wing or fuselage.

CHAPTER 6: Control Systems in Aerospace Engineering

- Fundamentals of control systems: open-loop and closed-loop systems.
- Stability and control in aerospace vehicles.
- Flight control systems: ailerons, elevators, rudders, and flaps.
- Autopilots and advanced control systems in spacecraft.
- Introduction to feedback systems in aerospace.
- Practical Application: Basic control system simulations for flight stability analysis.

CHAPTER 7: Control Systems in Aerospace Engineering

- Systems engineering process in aerospace.
- Integration of subsystems: propulsion, avionics, structures, and control.
- Requirements definition, design, testing, and validation in aerospace.
- Life cycle analysis of aerospace systems.
- Introduction to project management in aerospace engineering.

Practical Application: A group project to design a basic aerospace system (e.g., a drone or small satellite) considering all subsystems.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Fundamentals of Aerodynamics by John D. Anderson, Sixth Edition, McGraw Hill, 2016.
2. Introduction to Flight by John D. Anderson, Eighth Edition, McGraw Hill, 2015.

3. Airplane Aerodynamics and Performance, J. Roskam,, Part I, DARcorporation, 2016.

Teaching Unit	Subject Title	Code	Semester
UEF3.1.2	Electric Vehicles and Energy Systems	EVES	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	2h00	1h30	1h00	3/3

I. Course Objectives:

By the end of this course, students will:

- Understand the principles and technologies of electric vehicles and energy systems.
- Design and implement control and energy management algorithms for EVs.
- Analyze and address challenges in EV adoption, such as energy efficiency, charging infrastructure, and integration with renewable energy.

II. Targeted Skills:

Upon completing this section, students will have developed the following skills:

- Technical Skills:
 - Designing and implementing control and energy management algorithms for EVs.
 - Using simulation tools and platforms like MATLAB/Simulink.
- Analytical Skills:
 - Solving problems related to energy management, control, and optimization in EVs.
 - Evaluating and improving the performance of EV systems.
- Practical Skills:
 - Designing and testing EV solutions for real-world applications.
 - Debugging and optimizing EV systems.

III. Recommended prerequisites:

- Basic knowledge of electrical engineering and control systems.
- Familiarity with programming in Python or MATLAB.
- Introductory knowledge of energy systems and power electronics.

IV. Content:

This course introduces the principles and technologies behind electric vehicles and energy systems, focusing on the design, control, and integration of EVs with renewable energy sources. Students will gain hands-on experience with EV platforms and energy management systems.

Topics:

Chapter1: Introduction to Electric Vehicles and Energy Systems

- Overview of electric vehicles: types, components, and architectures.
- Applications in transportation, logistics, and mobility services.
- Challenges in EV adoption: range, charging infrastructure, and cost.

Chapter2: Electric Vehicle Powertrains

- Electric motors: types, characteristics, and control.
- Power electronics: inverters, converters, and controllers.

Chapter3: Energy Storage Systems

- Supercapacitors and hybrid energy storage systems.
- Energy density, power density, and lifecycle analysis.

Chapter4: Charging Infrastructure and Smart Grid Integration

- Charging technologies: AC, DC, and wireless charging.
- Smart grid integration and vehicle-to-grid (V2G) systems.
- Standards and protocols for EV charging.

Chapter5: Energy Management and Optimization

- Energy management strategies for EVs.
- Optimization techniques for energy efficiency.
- Predictive energy management using machine learning.

Chapter6: Renewable Energy Integration

- Integration of solar and wind energy with EV charging.
- Microgrids and distributed energy resources (DERs).
- Energy storage for renewable energy systems.

Chapter7: Control Systems for Electric Vehicles

- Motor control: field-oriented control (FOC) and direct torque control (DTC).
- Regenerative braking and energy recovery.
- Stability and safety considerations in EV control.

Chapter8: Simulation and Testing

- Hardware-in-the-loop (HIL) testing for EVs.
- Safety and validation of EV systems.

Chapter9: Advanced Topics

- Autonomous electric vehicles: perception, planning, and control.
- EV fleets.
- Ethical and environmental considerations in EV adoption.

Chapter10: Applications and Case Studies

- Electric vehicles in urban and highway environments.
- Electric buses and public transportation systems.
- Real-world challenges: scalability, robustness, and safety.

Laboratory Work

Lab 1: Simulation of Electric Vehicle Powertrain

Lab 2: EV Charging Infrastructure and V2G Systems

Lab 3: Motor Control Strategies for Electric Vehicles

Lab 4: Renewable Energy Integration with EV Charging

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam

- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

Bibliography

1. James Larminie & John Lowry – *Electric Vehicle Technology Explained* (Wiley, 2nd Edition, 2012)
2. Mehrdad Ehsani, Yimin Gao, & Ali Emadi – *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles* (CRC Press, 3rd Edition, 2018)
3. Sheldon S. Williamson – *Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles* (Springer, 2013)
4. Miroslav Krstic & Andrey G. Stefanopoulou – *Battery Management Systems: Control, Optimization, and Design* (Cambridge University Press, 2013)
5. Ronghui Liu et al. – *Vehicle-to-Grid: Energy Storage and Power Management for Electric Vehicles* (Springer, 2019)

Teaching Unit	Subject Title	Code	Semester
UEF3.1.2	Reinforcement Learning	REL	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h30	1h30	1h30	3/3

I. Course Objectives:

By the end of this course, students will:

- Understand the theoretical foundations of reinforcement learning.
- Implement and evaluate classic RL algorithms (e.g., Q-learning, SARSA, DQN).
- Apply RL techniques to solve decision-making problems in simulated and real-world environments.
- Analyze and address challenges in RL, such as exploration, scalability, and safety.

II. Targeted Skills:

Upon completing this section, students will have developed the following skills:

- Technical Skills:
 - Implementing RL algorithms from scratch.
 - Using RL frameworks (e.g., OpenAI Gym, TensorFlow, PyTorch).
- Analytical Skills:
 - Solving robotics problems using RL.
 - Evaluating and improving RL algorithm performance.
- Practical Skills:
 - Designing and training RL agents for robotics applications.
 - Debugging and optimizing RL systems.

III. Recommended prerequisites:

- Basic knowledge of probability and statistics.
- Programming experience in Python.
- Introductory knowledge of machine learning (supervised and unsupervised learning).

IV. Content:

This course provides a comprehensive introduction to reinforcement learning, a subfield of machine learning focused on decision-making and control. Students will learn the theoretical foundations of RL and gain hands-on experience implementing RL algorithms.

Topics:

Chapter1: Introduction to Reinforcement Learning

- Definition and key concepts: agent, environment, state, action, reward.
- Applications of RL: robotics, games, recommendation systems, and more.
- Comparison with supervised and unsupervised learning.

Chapter2: Markov Decision Processes (MDPs)

- Definition and components of MDPs.

- Policy, value functions, and Bellman equations.
- Solving MDPs: dynamic programming methods.

Chapter3: Model-Free RL Methods

- Monte Carlo methods: prediction and control.
- Temporal Difference (TD) learning: SARSA and Q-learning.
- On-policy vs. off-policy learning.

Chapter4: Function Approximation in RL

- Linear function approximation.
- Deep Reinforcement Learning: Deep Q-Networks (DQN).
- Policy gradient methods: REINFORCE, Actor-Critic.

Chapter5: Advanced RL Techniques

- Exploration vs. exploitation: epsilon-greedy, softmax, and Thompson sampling.
- Model-based RL: Dyna-Q and Monte Carlo Tree Search (MCTS).
- Multi-agent RL and competitive environments.
- Offline RL

Chapter6: Applications and Case Studies

- RL in robotics: control and navigation.
- RL in games: AlphaGo, OpenAI Five.
- Real-world challenges: sample efficiency, safety, and scalability.

Labs:

Hands-on implementation of RL algorithms using Python and frameworks like PyTorch, TensorFlow, or OpenAI Gym.

Lab 1: Introduction to Reinforcement Learning with OpenAI Gym

Lab 2: Implementing Q-Learning and SARSA

Lab 3: Deep Q-Networks (DQN) for Complex Environments

Lab 4: Policy Gradient Methods – REINFORCE and Actor-Critic

Lab 5: Applying RL to Robotics and Real-World Problems

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Richard S. Sutton & Andrew G. Barto – *Reinforcement Learning: An Introduction* (MIT Press, 2nd Edition, 2018)
2. David Silver – *Lecture Series on Reinforcement Learning* (DeepMind, available online)
3. Francois-Lavet et al. – *Deep Reinforcement Learning Hands-On* (Packt Publishing, 2nd Edition, 2020)
4. Maxim Lapan – *Deep Reinforcement Learning Hands-On* (Packt Publishing, 2nd Edition, 2020)
5. Berkeley CS285: Deep Reinforcement Learning Course (Available online)

Teaching Unit	Subject Title	Code	Semester
UEM3.1.1	Swarm Robotics and Multi-Agent Systems	SRMAS	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00	1h00	1h00	3/3

I. Course Objectives

- Understand the principles of swarm intelligence and multi-agent coordination.
- Develop algorithms for decentralized control and self-organization in robotic swarms.
- Explore applications of swarm robotics in real-world scenarios.
- Implement and test swarm behaviors using simulation tools and physical platforms.

II. Targeted Skills

- Technical Skills: Programming swarm behaviors, designing decentralized control algorithms.
- Analytical Skills: Evaluating swarm efficiency, optimizing multi-agent interactions.
- Practical Skills: Simulating and deploying swarm systems in real or virtual environments.

III. Recommended Prior Knowledge

- Fundamentals of control systems and robotics.
- Basic knowledge of artificial intelligence and optimization.
- Programming experience (Python, C++, or ROS).

IV. Content

Chapter 1: Introduction to Swarm Robotics

- Definition and characteristics of swarm robotics.
- Biological inspirations (ant colonies, bird flocking, fish schooling).
- Applications of swarm robotics.

Chapter 2: Fundamentals of Multi-Agent Systems

- Agents and environments.
- Types of multi-agent systems (MAS).
- Communication and cooperation strategies.

Chapter 3: Swarm Intelligence Algorithms

- Particle Swarm Optimization (PSO).
- Ant Colony Optimization (ACO).
- Artificial Bee Colony (ABC) and other heuristic approaches.

Chapter 4: Distributed Control and Coordination

- Decentralized vs. centralized control.
- Consensus and formation control.
- Task allocation and decision-making in swarms.

Chapter 5: Learning in Swarm Systems

- Reinforcement learning in multi-agent systems.
- Evolutionary strategies.
- Adaptive behavior in dynamic environments.

Chapter 6: Applications and Case Studies

- Swarm robotics in search and rescue.
- Agricultural and environmental monitoring.
- Military and security applications.

Lab Work

1. Swarm Simulation: Implementing swarm behaviors using Gazebo/ROS or Python-based simulators.
2. Decentralized Control: Programming robots to achieve flocking and formation control.
3. Swarm Optimization: Solving optimization problems with PSO and ACO.
4. Multi-Agent Coordination: Task allocation and communication in robotic swarms.
5. Real-World Deployment: Testing small-scale swarm behavior on physical robots (e.g., Turtlebots, Crazyflie drones).

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. E. Şahin & W. M. Spears, *Swarm Robotics: From Biology to Robotics*, Springer, 2005.
2. H. Hamann, *Swarm Robotics: A Formal Approach*, Springer, 2018.
3. M. Dorigo & T. Stützle, *Ant Colony Optimization*, MIT Press, 2004.
4. Y. Shoham & K. Leyton-Brown, *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations*, Cambridge University Press, 2009.
5. R. D'Andrea & M. Babish, *Distributed Robotics: From Algorithms to Strategies*, IEEE, 2016.

Teaching Unit	Subject Title	Code	Semester
UEM3.1.1	Unmanned Systems Practical Cases	USPC	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	3h00			3/3

I. Course Objectives

The objective of this course is to provide students with a comprehensive understanding of unmanned systems (UAVs, autonomous vehicles, and other unmanned platforms) through practical case studies. The course aims to equip students with the knowledge and hands-on experience necessary to analyze, design, and optimize unmanned systems for various real-world applications, including military, commercial, and research-based missions.

II. Targeted Skills

By the end of the course, students will be able to apply their theoretical understanding to real-world problems and gain experience in the design, operation, and testing of unmanned systems.

III. Recommended Prior Knowledge

Students should have a solid background in:

- Basic knowledge of control systems and robotics.
- Familiarity with sensors, communication systems, and power management.
- Understanding of programming and algorithms for autonomous navigation.

IV. Content

CHAPTER 1: Introduction to Unmanned Systems

- Overview of unmanned systems and their categories: UAVs, UGVs, UUVs, USVs.
- History and evolution of unmanned systems.
- Applications of unmanned systems in various industries: defense, agriculture, logistics, surveillance, and search and rescue.
- Regulatory and ethical considerations: airspace management, safety, and privacy concerns.

CHAPTER 2: Design Principles of Unmanned Systems

- Requirements analysis for unmanned systems: mission objectives, payloads, environment, and constraints.
- Design trade-offs: cost, weight, endurance, range, and power requirements.
- Selection of components: propulsion, avionics, sensors, and communication systems.
- Integration of subsystems and ensuring system reliability.

CHAPTER 3: Autonomous Control Systems

- Basics of control theory and autonomous navigation.
- Sensor fusion for perception: LIDAR, GPS, cameras, and IMUs.
- Path planning, trajectory generation, and obstacle avoidance.
- Communication systems for coordination and control (e.g., remote piloting, autonomous operations).

- Fail-safe mechanisms and robustness in autonomous systems.

CHAPTER 4: Power Systems in Unmanned Vehicles

- Power sources for unmanned systems: batteries, fuel cells, hybrid systems.
- Power management and optimization for extended mission endurance.
- Energy-efficient flight and vehicle optimization strategies.

CHAPTER 5: Communication and Data Link Systems

- Communication protocols for unmanned systems: radio frequency (RF), satellite communication, and 4G/5G.
- Data link systems: telemetry, real-time data streaming, and remote control.
- Challenges in communication: range, latency, bandwidth, and interference.
- Secure communication and data integrity for military and civilian applications.

CHAPTER 6: Sensors and Payloads for Unmanned Systems

- Overview of sensors: cameras, LIDAR, radar, infrared, and multispectral sensors.
- Payload design considerations: weight, power consumption, and compatibility with vehicle systems.
- Integration of payloads with control systems for mission-specific applications (e.g., surveillance, mapping, search and rescue).
- Real-time data processing and decision-making based on sensor inputs.

CHAPTER 7: Real-World Case Studies

- Case study 1: UAVs in agricultural monitoring and crop analysis.
- Case study 2: UAVs in disaster response and search-and-rescue operations.
- Case study 3: Autonomous vehicles for logistics and delivery.
- Case study 4: Military and defense applications of unmanned systems.
- Case study 5: Environmental monitoring using unmanned systems.

CHAPTER 8: Testing and Validation of Unmanned Systems

- Testing methodologies for unmanned systems: hardware-in-the-loop, software-in-the-loop, and field testing.
- Performance evaluation: flight testing, mission completion, sensor accuracy, and environmental impact.
- Safety protocols and risk management during testing and operation.
- Validation of system autonomy and fail-safety mechanisms.

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators, and Algorithms by Nikolaus Correll et al, The MIT Press, 2022.
2. Unmanned Aircraft Systems: UAVS Design, Development and Deployment by Reg Austin, John Wiley & Sons Inc, 2010.
3. Autonomous Robots: Modeling, Path Planning, and Control by Farbod Fahimi, Springer, 2008.
4. Online resources: Engineering software and simulation tools for unmanned systems

Teaching Unit	Subject Title	Code	Semester
UET3.1.1	Biomimetisme and Bio-inspired Robotics	HBIR	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00		1h00	3/3

I. Course Objectives

- **Introduce** **Biomimetics** **Concepts:**
Explore the principles of biomimetics and understand how biological systems inspire innovative robotic designs.
- **Analyze** **Natural** **Models:**
Develop the ability to study biological locomotion, sensing, and structural adaptations to inform robotic design.
- **Design** **Bio-inspired** **Systems:**
Equip students to apply bio-inspired design methodologies in developing adaptive, efficient, and resilient unmanned systems across aerial, terrestrial, and underwater domains.
- **Integrate** **Theory** **and** **Practice:**
Combine theoretical knowledge with hands-on laboratory work to prototype and test bio-inspired robotic mechanisms.

II. Targeted Skills

- **Analytical** **Skills:**
Critically assess natural systems to extract design principles applicable to robotics.
- **Design** **Methodologies:**
Employ abstraction techniques to translate biological inspiration into robust mechanical and control solutions.
- **Computational** **Modeling:**
Utilize simulation tools for the modeling and analysis of bio-inspired mechanisms.
- **Laboratory** **Prototyping:**
Build and test small-scale prototypes that incorporate bio-inspired features, integrating sensors and actuators.
- **Interdisciplinary** **Integration:**
Collaborate across fields (biology, robotics, materials science) to innovate and optimize unmanned system designs.

III. Recommended Prerequisites

Students entering this course should be familiar with:

- **Robotics** **Fundamentals:**
Basic principles of unmanned systems design, navigation, and control.
- **Control** **Theory** **and** **Sensor** **Integration:**
Understanding of feedback control systems and sensor data fusion.
- **Mechanical** **Design** **and** **Simulation:**
Exposure to CAD tools and computational simulation techniques.

- **Introductory** **Biomimetics:**
Basic concepts of biological systems and their functions (helpful but not mandatory).

IV. Content

1. Biomimetic Mechanisms

- 1.1 Introduction
- 1.2 Inchworm Locomotion
- 1.3 Walking Machines
- 1.4 Autonomous Footstep Planning
- 1.5 Principles of Bird Flight
- 1.6 Mechanisms Based on Bird Flight
- 1.7 Swimming Like a Fish

2. Biomimetic Sensors and Actuators

- 2.1 Action Potentials
- 2.2 Measurement and Control of Cellular Action Potentials
- 2.3 Bionic Limbs: Interfacing Artificial Limbs to Living Cells
- 2.4 Artificial Muscles: Flexible Muscular Motors
- 2.5 Prosthetic Control of Artificial Muscles
- 2.6 Bio-inspired Materials and tissues

3. Applications in Computer-Aided Surgery and Manufacture

- 3.1 Steady Hands: Active Tremor Compensation
- 3.2 Design of Scalable Robotic Surgical Devices
- 3.3 Robotic Needle Placement and Two-Hand Suturing

4. Dynamics and Balance of Walking Biped Robots

- 4.1 Dynamic Model for Walking
- 4.2 Dynamic Balance during Walking: The Zero-Moment Point
- 4.3 Half-Model for a Quadruped Robot: Dynamics and Control

5. Modeling Bird Flight: Robot Manipulators in Free Flight

- 5.1 Dynamics of a Free-Flying Space Robot
- 5.2 Controlling a Free-Flying Space Robot

6. Flapping Propulsion of Aerial Vehicles

- 6.1 Unsteady Aerodynamics of an Aerofoil
- 6.2 Generation of Thrust
- 6.3 Controlled Flapping for Flight Vehicles
- 6.4 Underwater Propulsion and Its Control

Laboratory Work

Lab 1 : Biomimetics Concept and Design

Lab 2 : Simulation of Natural Locomotion

Lab 3 : Sensor Integration Inspired by Nature

Lab 4: Prototyping Bio-inspired Mechanisms

Lab 5 : Evaluation and Optimization

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Bar-Cohen, Y. (2006). *Biomimetics: Biologically Inspired Technologies*. Taylor & Francis.
2. Vincent, J. F. V., & Mann, D. L. (2002). *Biomimetics: Its Practice and Theory*. Journal of the Royal Society Interface.
3. Ijspeert, A. J. (2008). *Central Pattern Generators for Locomotion Control in Animals and Robots: A Review*. Neural Networks.

Teaching Unit	Subject Title	Code	Semester
UET3.1.1	Industrial Automation	INA	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00		1h00	3/3

I. Course Objectives

This course aims to train students in the industrial automation technologies and methodologies that allow a production system to work automatically based on programmable logic controller (PLC) and SCADA systems.

II. Targeted Skills

By the end of this course, students will be able to:

- identify in an industrial system the different levels of a hierarchical automation.
- Choose for each level the most appropriate control strategies and the necessary technological elements
- Learn PLC programming languages.
- Design the automation in different areas such as energy, automated production systems, and smart buildings.
- Understand industrial communication and field buses.
- Understand Control Centers and SCADA systems
- Assess the reliability of an automation system

III. Recommended Prerequisites

- Basic knowledge of electronics
- Discrete even systems
- Boolean logic
- Communication protocols

IV. Content

Chapter 1 INTRODUCTION AND DEFINITIONS

- Importance of the automation of an industrial system. Basic concepts.
- Continuous processes, discrete processes, mixed processes, batch processing
- Sensors and drives

Chapter 2: ARCHITECTURE OF AN AUTOMATION PROCESS

- Functional and physical architecture. Automation pyramid.
- Technological elements : sensor networks, fieldbuses, controllers (PLCs), RTUs, local area networks and control centers
- OSI communications model. Control types: centralized, distributed. Real time control.

Chapter 3: DISCRETE PROCESSES CONTROL

- Boole Algebra
- GRAFCET
- GEMMA

Chapter 4: WIRED LOGIC

- Typical devices used
- Sequential logic
- Combinational logic

Chapter 5: PLC PROGRAMMING:

- Main parts of a PLC
- Ladder diagram language. Instruction language. Functional block language. Structure text language
- Execution models

Chapter 6: INDUSTRIAL COMMUNICATIONS:

- Network types. OSI model.
- Sensor networks. Device networks. Fieldbus networks.
- Industrial standards.
- Industrial examples

Chapter 7: CONTROL CENTERS

- Supervision and control systems (SCADA)..
- Basic models of organization.
- Man/machine interface design..
- Web Technology

Chapter 8: RELIABILITY OF AN AUTOMATION SYSTEM

- Definitions and Architectures.
- Reliability analysis..
- Standardization
- Cases study.

Labs:

Lab 1: Wired logic : use of combinational and sequential logic for wired systems

Lab 2: PLC programming : Basic and advanced programing on TIA portal by Siemens

Lab 3: HMI programming of HMI panel for process interfacing

Lab 4: Grafcet Programming of GRAPH language under TIA portal by Siemens

Lab 5: Small scale factory project of different technologies

Evaluation Method

- Module average = 20% continuous assessment + 20% practical Lab work + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Olushola Akande, 'Industrial Automation from Scratch: A hands-on guide to using sensors, actuators, PLCs, HMIs, and SCADA to automate industrial processes', Packt Publishing 2023;
2. Stamatios Manesis, George Nikolakopoulos, 'Introduction to Industrial Automation', CRC Press 2018.
3. Jon Stenerson, 'Industrial Automation and Process Control', Pearson college 2002.
4. Geoffrey Williamson, 'Industrial Automation: Systems and Engineering', States Academic Press, 2022.
5. Mikell Groover, 'Automation, Production Systems, and Computer-Integrated Manufacturing' Pearson college 2014.

6. KATARIYA SANJAY B, 'Industrial automation solutions for plc, scada, drive and field instruments: easy to learn industrial automation', Notion Press 2020.

Teaching Unit	Subject Title	Code	Semester
UED3.1.1	Training Internship III	TI-III	S9

Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH			1/1

I. Course Objectives

- Develop expertise in an area of specialization.
- Take ownership of a project or task within the company.
- Prepare students for career readiness and industry expectations.

II. Targeted Skills

- Leadership and initiative.
- Complex problem-solving.
- Professional networking.
- Industry-standard technical competencies.

III. Recommended prerequisites

- Advanced understanding of unmanned systems and control.
- Experience with project execution and troubleshooting.

IV. Content

- 1. Advanced Project Engagement**
 - Working on a specific problem-solving project.
 - Coordinating with team members on deliverables.
- 2. Independent Task Management**
 - Taking responsibility for assigned tasks.
 - Implementing improvements and optimizations.
- 3. Industry Networking and Career Preparation**
 - Engaging with professionals and industry leaders.
 - Learning about career pathways and opportunities.
- 4. Final Presentation and Evaluation**
 - Presenting project outcomes to company and faculty.
 - Self-assessment and feedback integration.

Evaluation Method

- Module average = 100% continuous assessment
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

- Internship & Career Handbook by Lauren Berger
- The Start-Up of You by Reid Hoffman

Teaching Unit	Subject Title	Code	Semester
UED3.1.1	Capstone Project IV	CP-IV	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00		4h00	2/2

I. Course Objectives

- Conduct independent research under faculty supervision.
- Aim for publication or market-ready product development.

II. Targeted Skills

- Research methodology and critical analysis.
- Scientific writing and publication.
- Entrepreneurial mindset.

III. Recommended prerequisites

- Research methodologies.
- Patent and publication process.

IV. Content

1. **Individual Research Project Development**
 - Literature review and research proposal.
 - Experimental design and data collection.
2. **Potential for Publication or Market Application**
 - Writing research papers and patents.
 - Business and commercialization strategies.

Evaluation Method

- Module average = 100% continuous assessment
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

- Research Methodology: A Step-by-Step Guide for Beginners by Ranjit Kumar
- From Idea to Startup: How to Start a Business by David Kidder

Teaching Unit	Subject Title	Code	Semester
UED3.1.1	Academic Communication and Research	ACR	S9

	Lectures	TUTORIAL	LABS	Crédit/ Coeff
VHH	1h00			1/1

I. Course Objectives

- Equip students with effective academic research, writing, and presentation skills.
- Familiarize students with literature search strategies and scientific databases.
- Introduce tools and techniques for writing scientific reports and articles using LaTeX and reference management tools.
- Develop skills for presenting research effectively.
- Raise awareness about ethical practices in academic research and publishing.

II. Targeted Skills

- Scientific literature search and review techniques.
- Academic writing using LaTeX and bibliographic tools.
- Research article/report structuring and publishing processes.
- Oral and visual presentation skills.
- Understanding and application of research ethics.

III. Recommended Prerequisites

- Basic computer skills.
- General familiarity with scientific/technical reading.
- Introductory knowledge of research methodology (recommended, not mandatory).

IV. Course Content

1. Literature Search

- Introduction to Literature Review
- Search Strategies and Tools (keywords, Boolean operators)
- Scientific Databases: IEEE Xplore, ScienceDirect, Scopus, Google Scholar
- Evaluating Source Credibility and Relevance

2. Academic Writing and Publishing

- Basics of LaTeX for academic writing
- Bibliography Management: BibTeX, Zotero, Mendeley
- Writing Scientific Reports and Articles
 - Structure: Abstract, Introduction, Methodology, Results, Discussion, Conclusion
 - Language and Clarity
- Publishing Process Overview
 - Choosing Journals, Submission, Peer Review

3. Presentation Skills

- Principles of Effective Presentation
- Slide Design and Visual Aids

- Tools: PowerPoint, LaTeX Beamer, Canva
- Public Speaking Techniques and Audience Engagement

4. Research Ethics

- Academic Integrity and Plagiarism
- Authorship and Contribution Ethics
- Ethical Conduct in Research and Data Handling
- Case Studies and Best Practices

5. Practical Wrap-Up

- Hands-on tasks and mini-presentations
- Peer and Instructor Feedback

Evaluation Method

- Module average = 40% continuous assessment + 60% final exam
- The level threshold is a grade equal to 60% of the average of grades obtained by all students in the cohort for the subject.
- The maximum value of the level threshold is set at 10/20.

V. Bibliography

1. Kidder, A. G. (Suggested reference for general communication and innovation strategies)
2. Day, R. A., & Gastel, B. *How to Write and Publish a Scientific Paper*
3. Alley, M. *The Craft of Scientific Writing*
4. Turabian, K. L. *A Manual for Writers of Research Papers, Theses, and Dissertations*
5. Lamport, L. *LaTeX: A Document Preparation System*
6. University guidelines on Research Ethics and Plagiarism Policies
7. Tutorials and official documentation of Zotero, Mendeley, and LaTeX

Detailed programs for the tenth semester

Teaching Unit (UE)	Subject Title	Code	Semester
	Internship and Final Year Project	Final	S10

			Crédit/ Coeff
VHH	14 Weeks	1h30	30/30

Objectives

The Internship and Final Year Project serve as critical educational components designed to consolidate academic knowledge while developing professional competencies. These experiences provide students with structured opportunities to apply theoretical concepts in practical settings, develop technical problem-solving abilities, and demonstrate their capacity for independent work. Through these professional experiences, students refine their analytical skills, enhance their project management capabilities, and establish meaningful industry connections that facilitate their transition from academia to professional practice.

The Final Year Project focuses on guiding engineering students toward addressing a specific engineering and/or research challenge. This culminating project is partially conducted within a company or laboratory setting in the form of an internship, creating a seamless integration between academic requirements and real-world professional experience. This approach ensures graduates possess the comprehensive skill set required by employers in the autonomous systems sector while providing them with authentic exposure to industry practices and methodologies.

Evaluation Method

• Overall Module Evaluation Formula

Module Average = 20% Internship Assessment + 80% Final Year Project

• Final Year Project Grading Criteria

1. Manuscript Quality (Document Formatting, Writing Quality)
2. Oral Presentation (Speech Quality and Delivery, Slide Quality and Visual Presentation, Understanding and Response to Questions)
3. Supervisor Assessment (Student Engagement and Commitment)
4. Innovation (Novelty and Originality of Solutions Provided)

Note: The detailed evaluation criteria for the Final Year Project will be defined by the school's scientific committees.

Agreements and conventions

Decisions and Approvals of Administrative and Advisory Bodies

Department

Scientific Board

School Direction

Administration Board