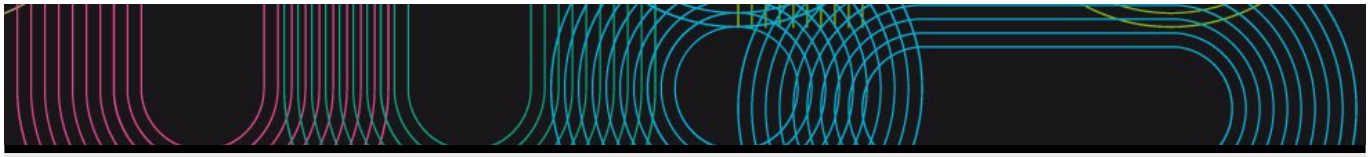

IDENTIFYING DATA				
Control systems				
Subject	Control systems			
Code	O07M189V01204			
Study programme	Máster Universitario en Sistemas Aéreos no Tripulados			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Optional	1st	2nd
Teaching language	#EnglishFriendly Spanish Galician			
Department				
Coordinator	García Rivera, Matías			
Lecturers	García Rivera, Matías			
E-mail	mgrivera@uvigo.es			
Web	http://www.galiciadrones.es/			
General description	This course describes fundamental concepts, principles and techniques about unmanned aerial vehicles: geometry, mechanics, hardware, control and navigation. English Friendly subject: International students may request from the teachers: a) materials and bibliographic references in English, b) tutoring sessions in English, c) exams and assessments in English.			

Skills	
Code	
A3	That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
A4	That students know how to communicate their conclusions -and the ultimate knowledge and reasons that support them- to specialized and non-specialized audiences in a clear and unambiguous manner.
A5	That students possess the learning skills that will enable them to continue studying in a manner that will be largely self-directed or autonomous.
B3	That students acquire the ability to analyze the needs of a company in the field of unmanned aerial systems and determine the best technological solution for it.
B4	That students acquire the knowledge to develop unmanned aerial systems and plan specific operations, depending on the existing needs and apply the existing technological tools.
B5	That students are able to apply, in the field of unmanned aerial systems, the principles and methodologies of research such as literature searches, data collection, data analysis and interpretation, as well as the presentation of conclusions, in a clear, concise and rigorous manner.
C1	Knowledge about the main systems, on-board instruments and control station of an unmanned aircraft, as well as their influence on safety.
C3	Ability to interact with other technical teams in the engineering field for the planning of operations with unmanned aerial systems.
C4	Ability to develop a technical project in the field of unmanned aerial systems engineering.
D6	Ability to work as part of a team.
D7	Organizational and planning skills.
D8	Capacity for analysis and synthesis.
D9	Critical thinking skills and creativity.

Learning outcomes	
Expected results from this subject	Training and Learning Results

RA01: Acquire knowledge about unmanned aerial robots, their key components, state estimation, basic mechanics, design considerations, agility and maneuverability.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA02: Know the geometric and mechanical considerations of unmanned aerial vehicles, transformations, rotations, Euler angles, applicability of quaternions, angular velocity, equations of movement of a multi-rotor, linearization.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA03: Understand the bases of the control and navigation system, PID controls, control in 1D, 2D and 3D of multirotor, generation of trajectories, Euler-Lagrange equations and Splines.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA04: Understand the operation of multiple control systems.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA05: Know the sense & avoid devices.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9

RA06: Understand the basics of embedded systems in real time.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9
RA07: Know the different existing open hardware controllers and their operation.	A3 A4 A5 B3 B4 B5 C1 C3 C4 D6 D7 D8 D9

Contents	
Topic	
Introduction to unmanned aerial vehicles.	Multi-rotors.
Key components of autonomous flight.	Estimation of states. Basic mechanics Design considerations Agility and maneuverability Selection of components.
Geometry and mechanics.	Transformations Rotations Angles of Euler. Quaternions Angular velocity. Newton-Euler equations. Main axes and main moments of inertia. Equations of movement of a multi-rotor. Linearization
Control and navigation.	PID control. 1D, 2D and 3D control of multirotor. Paths. Euler-Lagrange equations. Splines.
Control of multiple systems.	
Sense & avoid devices.	
Fundamentals of embedded systems in real time.	
Open hardware controllers.	

Planning

	Class hours	Hours outside the classroom	Total hours
Lecturing	10	0	10
ICT suppoted practices (Repeated, Dont Use)	10	15	25
Problem solving	10	15	25
Seminars	2	0	2
Mentored work	8	72	80
Problem and/or exercise solving	2	6	8

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies

	Description
Lecturing	Exhibition by the teacher of the contents on the subject.
ICT suppoted practices (Repeated, Dont Use)	Activities of application of knowledge to concrete situations and acquisition of basic and procedural skills related to the subject. They are developed through ICT in an autonomous way.
Problem solving	Activity in which problems related to the subject are formulated. The students must develop the solutions. The objective is that the students apply the theoretical contents in the resolution of small programming problems.
Seminars	Orientation activity for students.
Mentored work	The student, individually or in groups, prepares a document on the topic of the subject or prepares seminars, investigations, reports, essays, summaries of readings, conferences, etc.

Personalized assistance

Methodologies	Description
Mentored work	Tutorials in the teacher's office. It is advisable to go to these tutorials when difficulties appear in the development of the supervised work, or when the time dedicated to the non-contact activities significantly exceeds the time set in the planning.
ICT suppoted practices (Repeated, Dont Use)	Tutorials in the teacher's office. It is advisable to attend these tutorials when difficulties arise in the development of autonomous practices through ICT, or when the time spent on non-contact activities significantly exceeds the time set in the planning.

Assessment

	Description	Qualification	Training and Learning Results
ICT suppoted practices (Repeated, Dont Use)	2 assignments of autonomous practices through ICT, each one will contribute 15% of the overall mark for this course	30	A3 B3 C1 D6 A4 B4 C3 D7 A5 B5 C4 D8 D9
Mentored work	1 assignment of supervised work, it will contribute 20% of the overall mark for this course	20	A3 B3 C1 D6 A4 B4 C3 D7 A5 B5 C4 D8 D9
Problem and/or exercise solving	2 written exams, short answer tests, about the contents and competences taught in the lectures and autonomous practices through ICT. These tests will be short answer, each one will contribute 25% of the overall mark for this course.	50	A3 B3 C1 D6 A4 B4 C3 D7 A5 B5 C4 D8 D9

Other comments on the Evaluation

ASSESSMENT FOR ASSISTANTS IN 1ST EDITION: CONTINUOUS EVALUATION.

For the students attending the 1st edition (continuous evaluation) the following tests and deliveries will be made:

- 1 assignment of supervised work, it will contribute 20% of the overall mark for this course;
- 2 assignments of autonomous practices through ICT, each one will contribute 15% of the overall mark for this course;
- 2 written exams, short answer tests, about the contents and competences taught in the lectures and autonomous practices through ICT. These tests will be short answer, each one will contribute 25% of the overall mark for this course.

To pass the subject it is mandatory that the student make all the assignments and all the written exams, and that in each assignment and written exam obtain a mark equal to or higher than 4.0.

In the case of not making any assignments or written exam, or obtain in any assignments or written exam a mark lower than 4.0, if the overall mark is higher than 5, the final mark in the minutes will be 4.9, fail.

ASSESSMENT FOR NON ASSISTANTS IN 1ST EDITION.

For the students attending the 1st edition (non continuous evaluation) the following tests and deliveries will be made:

- 1 assignment of supervised work, it will contribute 20% of the overall mark for this course;
- 2 assignments of autonomous practices through ICT, each one will contribute 15% of the overall mark for this course;
- 1 written exam about the contents and competences taught in the lectures and autonomous practices through ICT. This test will be short answer and it will contribute 50% of the overall mark for this course.

To pass the subject it is mandatory that the student make all the assignments and all the written exams, and that in each assignment and written exam obtain a mark equal to or higher than 4.0.

In the case of not making any assignments or written exam, or obtain in any assignments or written exam a mark lower than 4.0, if the overall mark is higher than 5, the final mark in the minutes will be 4.9, fail.

ASSESSMENT FOR 2ST EDITION AND OTHER EDITIONS

The same assessment for non assisstans in 1st edition

JUSTIFICATION OF ABSENCE

To be able to justify the absence to a exam is required a Certificate of Absence or a Consultation and Hospitalization Certificate (also called P10) issued by the SERGAS doctor, or a certificate issued by a doctor. A proof of the doctor's appointment will not be valid

Sources of information
Basic Bibliography
Randal Beard, Timothy McLain, **Small Unmanned Aircraft: Theory and Practice**, Princeton University Press, 2012
Complementary Bibliography
Michael Cook, **A Linear Systems Approach to Aircraft Stability and Control**, Butterworth-Heinemann, 2007
Katsuhiro Ogata, **Ingeniería de control moderna**, PRENTICE HALL, 2010
Hassan Gomaa, **Real-time software design for embedded systems**, Cambridge University Press, 2016
Plamen Angelov, **Sense and Avoid in UAS Research and Applications**, John Wiley & Sons, Ltd, 2012
https://px4.io/,

Recommendations

Subjects that it is recommended to have taken before
Unmanned aerial systems operations/O07M174V01102
On-board sensors/O07M174V01104