AEEE551 - Nonlinear and Adaptive Control

<table>
<tr><td>Course Title</td><td colspan="5">Nonlinear and Adaptive Control.</td></tr>
<tr><td>Course Code</td><td colspan="5">AEEE551</td></tr>
<tr><td>Course Type</td><td colspan="5">Technical Elective</td></tr>
<tr><td>Level</td><td colspan="5">MSc (Level 2)</td></tr>
<tr><td>Year / Semester</td><td colspan="5">1 or 2</td></tr>
<tr><td>Teacher's Name</td><td colspan="5">Assoc. Prof. Marios Lestas</td></tr>
<tr><td>ECTS</td><td>8</td><td>Lectures / week</td><td>3</td><td>Laboratories/week</td><td>0</td></tr>
<tr><td>Course Purpose</td><td colspan="5">The aim of the course is to familiarize students with the analytical tools associated: (a) with the analysis of nonlinear systems focusing on their stability properties and their transient behavior around the equilibrium points, and (b) their feedback control design based on Lyapunov techniques such as backstepping and sliding mode control and also adaptive control techniques which aim to address the time varying nature of system behavior with online parameter identification techniques.</td></tr>
<tr><td>Learning Outcomes</td><td colspan="5">By the end of the course, students must be able to:
1. Describe and apply phase plane techniques.
2. Determine the qualitative behaviour of systems near equilibrium points.
3. Apply Poincare-Bendixson theory to determine the asymptotic behaviour of planar flows.
4. State and apply Stability theorems of Lyapunov and converse theorems.
5. Implement LaSalle's Invariance Principle.
6. Apply and Analyse Nonlinear Controller Design Techniques: Backstepping, Feedback Stibilization and Sliding Mode Control.
7. Apply and analyse on line parameter identification techniques based on gradient algorithms, least squared algorithms and SPR Lyapunov design. Analyse the effect of normalization and projection.
8. Apply and analyse direct and indirect model reference adaptive control with and without normalized adaptive laws.
9. Apply and Analyse Adaptive Pole Placement Control.</td></tr>
<tr><td>Prerequisites</td><td colspan="2">None</td><td colspan="2">Corequisites</td><td>None</td></tr>
<tr><td>Course Content</td><td colspan="5">Planar Dynamical Systems: Phase plane techniques, Qualitative behaviour near equilibrium points, Limit Cycles – Poincare-Bendixson theory.
Lyapunov Stability Definitions: Basic stability theorems of Lyapunov,</td></tr>
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	Lyapunov Direct and Indirect Method, LaSalle's Invariance Principle, Converse Theorems. **Lyapunov-Based Design Feedback Stabilization:** Backstepping, Sliding mode control. **Real-Time Parameter** Linear and Bilinear Parametric Models, Parameter identifiers and algorithms: SPR-Lyapunov Design. Gradient methods, Least squares methods, Normalized Laws, Persistence of Excitation. **Model Reference Adaptive Control**: The MIT Rule, MRAC design using Lyapunov Theory. Direct and Indirect MRAC control, Normalized and Unnormalized Adaptive Laws. **Adaptive Pole Placement Control Scalar case:** Polynomial approach, State-variable approach. **Adaptive Control of Nonlinear Systems:** Model Reference control for nonlinear systems, Adaptive control of linearizable minimum phase systems.
Teaching Methodology	Students are taught the course through lectures (3 hours per week) in classrooms or lectures theatres, by means of traditional tools or using computer demonstration. Auditory exercises, where examples regarding matter represented at the lectures, are solved and further, questions related to particular open-ended topic issues are compiled by the students and answered, during the lecture or assigned as homework. Topic notes are compiled by students, during the lecture which serve to cover the main issues under consideration and can also be downloaded from the e-learning platform or the lecturer's webpage. Students are also advised to use the subject's textbook or reference books for further reading and practice in solving related exercises. Tutorial problems are also submitted as homework and these are solved during lectures or privately during lecturer's office hours. Furthermore, design projects may be assigned to the students, where literature search is encouraged to identify a specific problem related to some issue, gather relevant scientific information about how others have addressed the problem, implement to implement the design and report the results in written or orally. Where appropriate, taught material as well as examples and design problems are drawn from the recent research activities of the lecturer or other faculty members.
Bibliography	**(a) <u>Textbooks:</u>** • H. K. Khalil, **Nonlinear Systems**, 3rd edition, Prentice Hall, 2001. • Ioannou & Sun, **Robust Adaptive Control**, Prentice Hall, 1996. (required) (comment: Free on-line text available.) **(b) <u>References:</u>** • K.J. Astrom, B. Wittenmark, **Adaptive Control**: Second Edition, Dover Publications; 2nd edition, 2008 • S. Sastry, **Nonlinear Systems: Analysis, Stability, and Control**, Springer, 1999. • Krstic, Kanellakopoulos, and Kokotovic, **Nonlinear and Adaptive**

	Control Design, Wiley, 1995.
Assessment	The Students are assessed via continuous assessment throughout the duration of the Semester, which forms the Coursework grade and the final written exam. The coursework and the final exam grades are weighted 40% and 60%, respectively, and compose the final grade of the course. Various approaches are used for the continuous assessment of the students, such as mid-term written exam, oral exam, quizzes, design assignments and design projects. The assessment weight, date and time of each type of continuous assessment is being set at the beginning of the semester via the course outline. An indicative weighted continuous assessment of the course is shown below: • Assignments 10% • Homework 10% • Mid-Term written exams 40% • Design Project 20% • Quizzes 20% Students are prepared for final exam, by revision on the matter taught, problem solving and concept testing and are also trained to be able to deal with time constrains and revision timetable. The criteria considered for the assessment of each type of the continuous assessment and the final exam of the course are: (i) the comprehension of the fundamental concepts and theory of each topic, (ii) the application of the theory in solving related problems and (iii) the ability to apply the above knowledge in more complex design problems. The above criteria are weighted 30%, 40% and 30%, respectively. The final assessment of the students is formative and summative and is assured to comply with the subject's expected learning outcomes and the quality of the course
Language	**English**