Program: B. Tech. (ECE, CCE)	Course Title: Nonlinear and Adaptive Control Design			Course Code: ECE3112
Type of Course: Program Elective	Prerequisites: Control System			Total Contact Hours: 40
Year/Semester: 3rd/6	Lecture Hrs/Week: 2	Tutorial Hrs/Week: 1	Practical Hrs/Week: 0	Credits: 3

Learning Objective:

The objective of the course is to provide students with knowledge of different adaptive control system design and their challenges. Students will learn controller architectures, controller Design, stability assessment methods, Robustness analysis, and their implementation with MATLAB and various microcontrollers & microprocessors.

Course outcomes (COs):

On completion of this course, the students will have the ability to:		Bloom's Level
CO-1	Analyse the physical system for the controller design.	4
CO-2	Implementation of different PID controller design Methods on the microcontroller	6
CO-3	Analyse Non-linear systems for stability and Controller design.	4
CO-4	Design of Model Reference Adaptive Control on MATLAB and microcontrollers	6
CO-5	Design of Sliding Mode Control on MATLAB and microcontrollers	6

Course Topics		Lecture Hours
UNIT – I (Transportation Lag and PID controller Designs)		12
1.1 Transportation lag: Cause of Delay, Approximations of transportation lag.	2	
1.2 System Modelling: Transfer function modelling and State Space modelling.	2	
1.3 PID Controller Design: Internal Model Controller, Gain Margin and Phase margin Gain Scheduling and Adaptive PID.	4	
1.4 PID Controller implementation: Controller implementation on STM32 MCU, AVR MCU (Arduino), and Raspberry PI (ARM microprocessor) with MATLAB.	4	
UNIT – II (Introduction to Non-Linear Control system)		10
2.1 Types of nonlinearity, Plant Dynamics: Certain System: Time-varying, Time-Invariant, Uncertain System: Uncertain automated, uncertain Tolerated.	1	
2.2 Lyapunov Stability Criterion: Stability Definition, Asymptotic Stability, Exponential Stability	3	

2.3 Lyapunov's Direct Method: Lyapunov's Theorem, Radially Unbound Functions, Differential Lyapunov Equation	**3**	
2.4 Stability of Non-autonomous system: Uniform Stability, Uniform Boundedness, Barbalat's Lemma	**3**	
2.5 System Stability analysis with MATLAB	**2**	
UNIT – III (Model Reference Adaptive Control-(MRAC))		
3.1 Components of MRAC: Reference Model, Plant Model, Uncertain System, Control Law.	2	
3.2 Control Law design with Lyapunov's Function and Implementation on microcontroller/microprocessor	4	**10**
3.3 MCU implementation of Direct and Indirect MRAC for the first-order system, Limitations of MRAC	4	
UNIT – IV (Sliding Mode Control)		
4.1 Introduction to Intuitive theory of Sliding Mode Control	2	
4.2 Sliding Surface design, Observer Design, and Stability Analysis	3	**8**
4.3 Implementation and Design of Sliding Mode Controller for Yaw and Pitch Controller of Aircraft	3	

Textbook and Reference Books:

1. Datta, A. (1998). *Adaptive Internal Model Control*. Springer London.
2. Nguyen, N. T. (2018). Model-Reference Adaptive Control. In *Advanced Textbooks in Control and Signal Processing* (Issue 9783319563923, pp. 83–123). Springer International Publishing.
3. Shtessel, Y., Edwards, C., Fridman, L., & Levant, A. (2014). *Sliding mode control and observation* (Vol. 10). New York: Springer New York.
4. Åström, K. J., & Hägglund, T. (1995). PID controllers: theory, design and tuning [Book]. In *International Society of Automation* (Vol. 2). Instrument Society of America.

Additional Resources:

1. **https://web.mit.edu/nsl/www/videos/lectures.html**
2. **https://onlinecourses.nptel.ac.in/noc22_me129/preview**
3. **https://nptel.ac.in/courses/108102113**
4. **https://archive.nptel.ac.in/courses/108/105/108105180/**

Software and Hardware support:

1. **https://www.st.com/en/development-tools/stm32cubemx.html**
2. **https://www.st.com/en/development-tools/stm32cubeprog.html**
3. **https://in.mathworks.com/help/slcontrol/adaptive-control-design.html**
4. **https://in.mathworks.com/videos/series/understanding-pid-control.html**
5. **https://in.mathworks.com/help/supportpkg/raspberrypi/ref/getting-started-with-raspberry-pi-hardware.html**
6. **https://in.mathworks.com/help/supportpkg/arduino/index.html**

Evaluation Method*		Associated COs
Item	Weightage (%)	
Project 1 (Simulink)	15	CO1, CO2
Project 2 (Simulink)	15	CO3, CO4
Midterm	30	CO1, CO2, CO3
Final Examination	40	CO3, CO4, CO5

CO and PO Correlation Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	3	3				1	2		3	3	1	1
CO2	3	3	3	2	3				1	2		3	3	1	1
CO3	3	3	1	2	2				1	2		3	3	1	1
CO4	3	2	3	2	3				1	2		3	3	1	1
CO5	3	3	3	3	3				1	2		3	3	1	1

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Prepared By: Dr. Bharat Verma **Approved By:**

Updated By: