Course Number : AR510
Course Name : Underactuated Robotics
Credit Distribution : 3-0-0-3
Intended for : UG, PG and PhD
Prerequisite : Consent of faculty advisor
Mutual Exclusion : None

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1. Preamble:

Robots today move far too conservatively, using control systems that attempt to maintain full control authority at all times. Humans and animals move much more aggressively by routinely executing motions that involve a loss of instantaneous control authority. Controlling nonlinear systems without complete control authority requires methods that can reason about and exploit the natural dynamics of our machines. This course introduces nonlinear dynamics and control of underactuated mechanical systems, with an emphasis on computational methods. Topics include the nonlinear dynamics of robotic manipulators, applied optimal and robust control, and motion planning. Discussions include examples from biology and applications to legged locomotion, compliant manipulation, underwater robots, and flying machines.

2. Course Modules with quantitative lecture hours:

Introduction to Underactuated Robotics: Motivation, Fully-actuated vs Underactuated systems, Feedback equivalence, Input and State constraints. **(6 hours)**

Robot dynamics and model-based control: Nonlinear dynamics with a constant torque, Acrobots, Cart-poles, and Quadrotors. **(6 hours)**

Dynamic programming: Lyapunov analysis; Trajectory optimization, Trajectory stabilization; Policy search; Multibody parameter estimation, Formulating control design as an optimization. **(6 hours)**

Simple models of walking and running: Limit cycles, Simple models of walking such as Rimless wheel, Compass gait, Kneed walker, Curved feet, Simple models of running such as Spring-loaded inverted pendulum (SLIP), Hopping robots, Toward human-like running. **(8 hours)**

Planning and control through contact: Sampling-based motion planning, Complete motion planning, Feedback motion planning, Planning as Combinatorial + Continuous Optimization. **(8 hours)**

Stochastic dynamics: Stochastic/ robust control, Master equation, Stationary distribution, Costs and constraints for stochastic systems, Finite Markov Decision Processes, From linear models to deep models. **(8 hours)**

3. Textbooks:

1. Tedrake R., Underactuated Robotics: Algorithms for Walking, Running, Swimming, Flying, and Manipulation, MIT Press.

4. References:

1. Xin X. and Liu Y., Control Design and Analysis for Underactuated Robotic Systems, Springer.
2. Birglen L., Laliberte T., and Gosselin C., Underactuated Robotic Hands, Springer.

5. Similarity with the existing courses:

(Similarity content is declared as per the number of lecture hours on similar topics)

S. No.		Course Code	Similarity Content	Approx. % of Content
1.		None	None	None

6. Justification of new course proposal if cumulative similarity content is >30%: None