ME Seminar

Impulsive Actuation for Stabilization of Periodic Motion in Underactuated Robots

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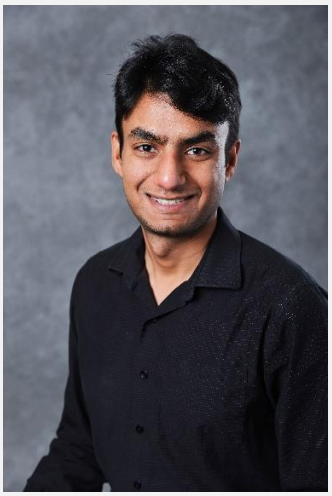
ABSTRACT

Robots have gained popularity due to their capability to perform complex tasks and operate in unknown and hazardous environments. Many of these robotic systems are underactuated, meaning they have fewer control inputs than degrees of freedom. Common examples include legged robots like bipeds, flying robots like quadrotors, and swimming robots. Underactuated systems are particularly challenging to control due to their limited control authority, making them prone to instability. This talk will showcase the utility of using impulsive actuation to address these control challenges. We will begin by reviewing the basics of impulsive actuation and preliminary results on equilibrium stabilization. Many applications require stabilization of periodic motions rather than equilibrium, such as legged locomotion, hopping, and swimming. The main focus will be on stabilizing periodic motions in underactuated robotic systems utilizing impulsive actuation. Two main control strategies will be presented. First, we will discuss energy-based orbital stabilization using continuous control, with intermittent impulsive braking inputs. This hybrid control scheme is designed to cause a monotonic decrease in a Lyapunov-like function, stabilizing the system at a desired energy level. Following this, we will delve into periodic motion stabilization using the Impulse Controlled Poincaré Map (ICPM) approach. In this approach, geometric constraints are enforced via a continuous controller to ensure the existence of a family of closed orbits. A desired orbit is selected based on required repetitive motion characteristics, and the periodic motion is stabilized using intermittent impulsive actuation. The talk will also present the design of impact-free biped gaits and their stabilization using this technique. We will address challenges posed by parameter uncertainty in periodic motion control, showing how extended high-gain observers can be used alongside the ICPM approach. Experimental results validating the control designs will be presented throughout the talk. We will conclude by discussing future directions for utilizing impulsive actuation in robotic applications.

ABOUT THE SPEAKER



Nilay Kant completed his B.Tech. in Mechanical Engineering from the Indian Institute of Technology (IIT) Delhi in 2015. He then pursued a Ph.D. in Mechanical Engineering at Michigan State University, East Lansing, from 2015 to 2020. During his doctoral studies, he was a visiting student researcher at the NASA Jet Propulsion Laboratory in Pasadena, California. After earning his Ph.D., Dr. Kant worked as a Senior Mechatronics and Control Engineer at Nexteer Automotive Corporation in Saginaw, Michigan, and as a Senior Controls Engineer at Mainspring Energy in Menlo Park, California. He is currently an Assistant Professor in the Department of Mechanical Engineering at Michigan State University.

Dr. Kant was honored with the Outstanding Graduate Student Award for his doctoral research at Michigan State University. He has authored around 18 papers in top peer-reviewed journals and conferences in robotics and control. His research interests include impulsive control, underactuated robots, dynamics and control of mechanical systems, assistive robotics, and energy-efficient technologies.

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