Graduate Colloquium, Aerospace Engineering

Navigation of Drones in Unknown Indoor Environments – Challenges and Opportunities

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Safe and reliable use of drones in indoor environments poses several challenges from technological perspectives when it comes to their beyond visual line of sight (BVLOS) operation. While autonomous navigation capabilities in drones in outdoor environment have been achieved (and available in commercially available drones), doing the same for indoor environment has been extremely elusive. The most fundamental challenge that has been preventing us from achieving this capability is carrying out localization, i.e., determining drone's 3D location. In absence of GPS, that is widely used for outdoor environment, indoor drones need to rely on, often noisy, onboard sensors (such as vision, laser, ultrasound) to carry out localization. Additionally, drone's operation in a complex indoor environment in proximity with humans and other obstacles leaves very little room for errors. Attempting to solve these problems using complementary and redundant sensors would result in higher payload, an unaffordable luxury for indoor drones, where payload constraints need to be tightly enforced to keep the drone size within limits. In this talk, I will present our work aimed at solving the above problems.

Our overall approach combines multi-sensor fusion method for localization with navigation, path planning, and obstacle avoidance in a human-centered fashion to achieve a safe and reliable flight in indoor environments. Results from adaptive Kalman Filtering that combines data from LiDAR based 3D SLAM with IMU and another 1D LiDAR will be presented. By combining the Dynamic Window Approach with an Artificial Potential Field method, we achieve robust, collision-free navigation that supports fully autonomous operation while allowing human supervision when needed. We will share insights from two use-cases of indoor drones: telehealth applications and warehouse inventory management.

Brief Bio: Manish Kumar received his Bachelor of Technology degree in Mechanical Engineering from Indian Institute of Technology, Kharagpur, India in 1998, and his M.S. and Ph.D. degrees in Mechanical Engineering from Duke University, NC, USA in 2002 and 2004 respectively. After finishing his Ph.D., he served as a postdoctoral researcher in the Department of Mechanical Engineering and Materials Science at Duke University, the US Army Research Office, and General Robotics, Automation, Sensing, and Perception (GRASP) laboratory at the University of Pennsylvania, PA, USA. He started his career as a faculty member at University of Cincinnati (UC) in 2007 in the Department of Mechanical and Materials Engineering where he currently serves as a Professor and the Graduate Program Director. He established Industry 4.0/5.0 Institute which is consortium of industry members engaged in researching and developing advanced technologies for solving key challenges facing the industry. He currently directs Cooperative Distributed Systems (CDS) Laboratory, co-directs Industry 4.0/5.0 Institute, and co-directs UAV MASTER Lab. His research interests include Unmanned Aerial Vehicles, robotics, decision-making and control in complex systems, AI, multi-sensor data fusion, swarm systems, and multiple robot coordination and control. His research has been supported by funding obtained from National Science Foundation, Department of Defense, Ohio Department of Transportation, Ohio Department of Higher Education, and several industrial partners. He is a member of the American Society of Mechanical Engineers (ASME). He has served as the Chair of the Robotics Technical Committee of the ASME's Dynamic Systems and Control Division, and as Associate Editor for the ASME Journal of Dynamic Systems, Measurements and Control and ASME Journal of Autonomous Vehicles and Systems.