Multi-agent control architectures in aerospace: from flying insect swarms to orbital debris cleanup

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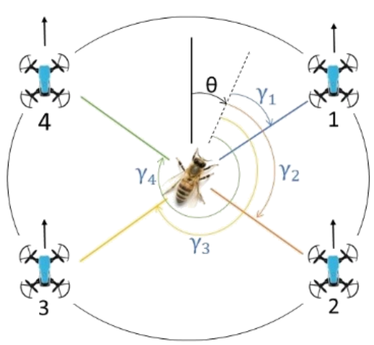
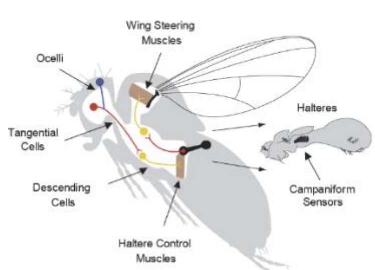
Abstract: This seminar develops tools for robust, visually-guided swarming of aerobatic aerospace vehicles, highlighting the differences in how traditional engineered approaches and biological systems approach this problem. The seminar begins with traditional engineered notions of robust aerospace control and proceeds to develop a framework to understand visually mediated insect flight responses through theoretical analysis, high speed insect flight experiments, and feedback control extraction. The results of this study are implementable visually guided flight controllers to achieve aerial swarming not dependent on an explicit communication network or position reference such as global positioning system (GPS).

The seminar begins by reviewing example uncertainties in robust aerospace control platforms, then establishes flight dynamics models of dipteran flapping wing insects by combining automated high speed videography measurements of freely flying insects, experimental aerodynamics, rigid body dynamics, and system identification techniques to distill high fidelity flight dynamics models into computationally-tractable models applicable to flight control analysis. System identification methods to extract models of the closed loop controllers implemented on insects from free flight trajectories are applied with inverse optimal control interpret the controllers into implementable design principles. Recent advances in experimental techniques to measure untethered multi-agent aerial insect flight behaviors are combined with insect visuomotor feedback and bifurcation analysis to show how the presence of social neighbors modulates the inherent individual heterogeneity in insect's visuomotor sensing and feedback neural structures, and to extract the coupled decision and control architectures that individuals use to support robust visually guided multi-agent behaviors. Robotic implementations illustrate the robust nature of the resulting swarming capability. Modeling of multi-agent systems are then applied to orbital debris proliferation and cleanup efforts.





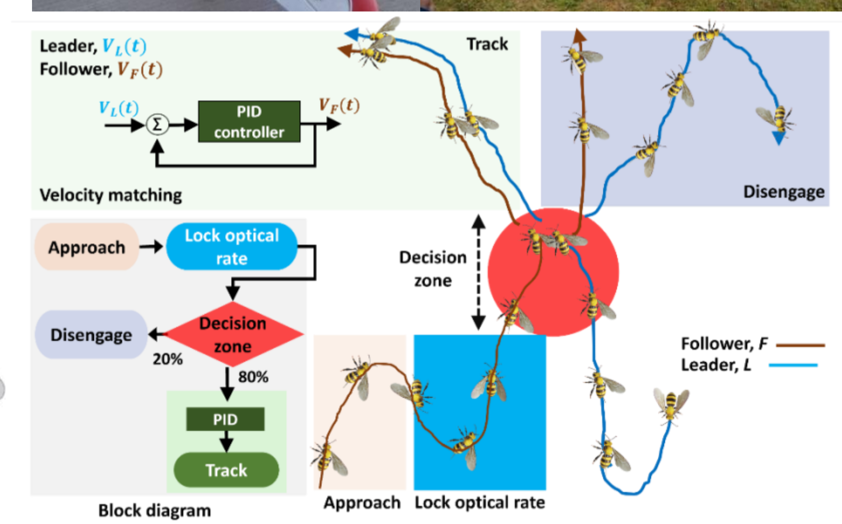


Figure 1. Imraan A. Faruque studies biologically inspired flight dynamics and control and unmanned systems

Bio: Imraan Faruque's research interests include reduced-order models of complex systems, biologically inspired locomotion and control systems, flight dynamics and control, and unmanned aerial systems. Dr. Faruque developed the first 6DOF insect flight dynamics models appropriate for controls studies, resulting in widespread community adoption. Dr. Faruque's specialization is in dynamic models of the feedback control of flying insects and in translating those strategies to engineered flight capabilities on unmanned aerial vehicles, where his work has led to numerous best paper awards and patents. He is a recipient of the 2019 ONR Young Investigator Award, OSU's 2023 Excellent Faculty Award, and the 2017 AIAA NCS Young Engineer/Scientist of the Year Award. He was a founding member of two university UAS test sites (Virginia Tech, University of Maryland), a founding member of the Oklahoma Aerospace Institute for Research and Education, and is a member of the OSU Brain Initiative.

Dr. Faruque is currently an Associate Professor at Oklahoma State University. He is a BS and Commonwealth Scholar alumnus of Virginia Tech, and received his MS (2010) and PhD in Aerospace Engineering in 2011 from the University of Maryland. He previously held research positions at the Army Research Lab, the Air Force Research Lab, General Electric Aircraft Engines, and University of Maryland.