

# NRI: FND: COLLAB: Distributed Bayesian Learning and Safe Control for Autonomous Wildfire Detection

Nikolay Atanasov<sup>1</sup> Sicun Gao<sup>2</sup> Tajana Rosing<sup>2</sup> Baris Aksanli<sup>3</sup>  
<sup>1</sup>ECE, <sup>2</sup>CSE, University of California San Diego <sup>3</sup>ECE, San Diego State University

## Motivation

- **Early detection** is a critical factor in mitigating wildfire damages to ecological systems and human infrastructure
- **Goals:** develop techniques for autonomous aerial robot teams for (A) online multi-modal terrain mapping, (B) collaborative localization, communication, and persistent monitoring, (C) nonlinear control with safety guarantees

## Task A: Online Multi-modal Terrain Mapping

- Mesh reconstruction from aerial images for outdoor terrain mapping using joint 2D-3D learning (**IEEE ICRA'21**)
- Dense incremental metric-semantic mapping for multi-agent systems via sparse Gaussian process regression of signed distance fields (**IEEE IROS'19, IEEE IROS'20, IEEE T-RO**, submitted)
- Distributed stochastic mirror descent algorithm for collaborative robot localization from local edge measurements (**IEEE CDC'20, IEEE CDC'19**)

## Task B: Communication- and uncertainty-aware UAV trajectory planning

- Bi-level optimization for UAV trajectory planning and uncertainty minimization in persistent monitoring applications (**IEEE ACC'19, IEEE T-RO**, in preparation)
- Frequency-aware trajectory and power control for multi-UAV systems; joint alternating optimization of trajectories, RF channel, RF power (**IEEE InfoCom DroneCom'21**)
- Efficient training on edge devices using online quantization (**IEEE DATE'20**)
- **Best paper nominee:** RESPIRE: Robust Sensor Placement Optimization in Probabilistic Environments (**IEEE Sensors'20, '21**)

## Task C: Nonlinear System Control with Safety and Stability Constraints

- Stabilizing neural control using self-learned almost Lyapunov critics (**NeurIPS'19, IEEE ICRA'21**)
- Provably efficient model-based policy adaptation (**ICML'20**)
- Inverse abstraction of neural networks using symbolic interpolation (**AAAI'19**)
- Numerically robust inductive proof rules for continuous dynamical systems (**CAV'19**)
- **First general framework for neural-network Lyapunov control**, increasing the region of attraction over LQR and SOS method

## Broader Impact (Education and Outreach)

- **UCSD-SDSU collaboration** to increase participation in robotics research
- **8 poster presentations led entirely by undergrads** at SDSU Student Research Symposium, UCSD Summer Research Conference, UCSD Research Expo
- **Undergrad student team** working on python sim of 3-D environments and algorithms for occupancy mapping, particle-filter localization, path planning
- **Joint presentation** (Feb'21) and **four hands-on tutorials and workshops** (April'21) at IEEE-HKN UCSD and SDSU chapters

## Broader Impact (Society)

- Connections with local companies: **STTR with Planck Aerospace**, joint UAV experiments planned with **SD fire department** and **FD1 drone**
- Datasets and joint work with the High-Performance Wireless Research and Education Network (**HPWREN**)

