Shijie Gao

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Autonomy | Learning-based Control | Adaptive Planning | Motion Prediction | Robotic Swarms | UGV & UAV Research

RESEARCH INTEREST

The main objective of my research is to establish a foundation for **autonomous mobile systems** to **predict**, **detect**, **adapt**, and **recover against failures** and **changes** in **systems' dynamics** at **runtime** while ensuring **safety**. My research focuses on developing **learning-based control** and **safe planning** techniques, incorporating principles from machine learning, optimal control, motion planning, reachability analysis, and transfer learning.

My collaboration works extend into the areas of **robotic swarms**, cyber-physical systems (**CPS**) security, Human-robot interaction (**HRI**), and autonomous inspection, etc.,

EDUCATION

University of Virginia *Aug.2017 – May. 2024 (Expected)*
Doctor of Philosophy, Computer Engineering

Beijing Institute of Technology *Aug. 2013 – July, 2017*
Bachelor of Science, Automation

University of California Berkeley *Aug. 2016 – May, 2017*
Exchange Student, Electrical Engineering and Computer Science

SKILLS

Proficient in **C++**, **MATLAB**, **Python**, Robot Operating System (**ROS1**, **ROS2**), **Gazebo**, **LINUX**

Proficient in **Assembling**, **Developing**, **Operating** and **Maintaining** a variety of robotic systems:

- **UGV**: Boston Dynamics Spot, Clearpath Jackal, Clearpath Ridgeback, Turtlebot 2/3/4, ROSBot, etc.,
- **UAV**: AscTec Hummingbird, AscTec Pelican, Crazyflie, DJI Matrice, DJI Mavi, Parrot Bebop, etc.,
- **Sensors**: RGB-D Camera, Thermal Camera, 2D/3D LiDAR, GPS etc.,
- **Other platforms**: Phidgets, DJI OSDK, Spot SDK, CasADi, Docker, Variety of Simulators, etc.,

RESEARCH EXPERIENCE

University of Virginia, Autonomous Mobile Robots Lab *Charlottesville, VA*
Graduate Research Assistant *Jan. 2018 - Now*

- Developed novel control and path planning techniques that improve the safety and efficiency of autonomous robotic systems operations, aiming to solve general challenges in robotic applications (e.g. **state and uncertainty predictions**, **task allocation**, **efficient path planning**, **optimal control**, **degradation recoveries**, etc.,)
- Validate the proposed techniques by **rapidly prototyping** software to control robotic simulators.
- Create proof-of-concept tests, using high-fidelity simulators and real-world robotic systems.
- Complete projects that demonstrate the efficacy of the proposed techniques in an **efficient and timely manner**.
- Authored several papers that **effectively communicate** the key concepts, selected for publication in prestigious robotics conferences and journals.
- Rapidly designed, assembled, and configured robotic platforms, while **also developing API tools** and **ROS wrappers** to fulfill the requirements of both lab projects and course teaching.
- Mentoring undergraduate capstone teams.

SELECTED RESEARCH

Bridging the Gap for Sim2Real and Real2Real Transfer Learning Challenges
***S. Gao**, and N. Bezzo, 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (**IROS 21'**) and* under review for Journal of Intelligent & Robotic Systems (**JINT**)

- Proposed a novel **conformal mapping-based** transfer framework that **rapidly adapts** the control and path planning policy across systems with different dynamics, bypassing accurate model learning.
- Optimal Control, Model Predictive Control (**MPC**), **Motion Primitives Planning**, Complex Analysis
- C++, Python, CasADi NLP, MATLAB, ROS; UGV

Sampling-Based Next-Best-View Task and Motion Planning for Autonomous Photography & Inspection
S. Gao**, L. Bramblett, and N. Bezzo, in **IROS 23' Workshop** and under review for **IROS 24'

- Presented a runtime task and motion planner using a proposed **spatial information gain** for choosing optimal inspection points in **partially known** environments with unknown obstacles and occlusion, ensuring thorough inspection with **minimum** number of photos.
- Gaussian Process (**GP**), **raytracing**, Derivative-free Optimization, Hybrid A*, RRT*
- C++, Python, MATLAB, ROS, Gazebo; UGV, UAV, Lidar, RGB-D camera, GPS

Meta-Learning-based Proactive Monitoring and Planning for Autonomous Systems under Degradations
***S. Gao**, E. Yel, and N. Bezzo, in IEEE Robotics and Automation Letters (**RA-L**)*

- Proposed a **Meta-Learning** based framework to predict and monitor the system's future states and state uncertainties under unforeseen actuator faults. Assuring the system safety by proactively replanning waypoints to prevent potential collisions.
- Model-Agnostic Meta-Learning (**MAML**), Mini-Jerk Trajectory Generation, **Runtime Model Adaption**
- Python, TensorFlow, ROS, Gazebo, MATLAB; UAV

Exploiting Air Dynamic Changes for Reliable and Efficient Autonomous UAV Motion Planning
S. Gao, C. Di Franco, D. Carter, D. Quinn, and N. Bezzo, in **ICUAS 19'**

- Designed a novel physical testbed for characterizing the ground and the ceiling effects for quadrotors. Proposed an **energy-efficient path planning** (up to **13%** energy reduction) strategy based on the analyzed airflow dynamics. Additionally, developed a **sensor-less** surface detection and landing method to enhance safety in quadrotor operation.
- Optimal Control, Polynomial Regression, Dijkstra
- Python, ROS, MATLAB; UAV

Epistemic Prediction and Planning for Robotic Swarms in Communication Restricted Environments
*L. Bramblett, **S. Gao**, N. Bezzo, in 2023 IEEE International Conference on Robotics and Automation (**ICRA 23'**)*

- Proposed a novel **epistemic planning** framework using **dynamic epistemic logic** for **distributed consensus-based planning.** The framework addresses generalized task allocation and space coverage problems, considering connectivity constraints and team dynamics.
- Distributed Control, Dynamic Epistemic Logic, Artificial Potential Field
- Python, MATLAB, ROS; Robotic Swarm

A Data-Driven Framework for Proactive Intention-Aware Motion Planning in Human Environment
R. Peddi, C. Di Franco, ***S. Gao***, and N. Bezzo, in **IROS 20'** [Human Robot Interaction]

Detection of Nonrandom Sign-Based Behavior for Resilient Coordination of Robotic Swarms
P.J. Bonczek, R. Peddi, ***S. Gao***, and N. Bezzo, in IEEE Transactions on Robotics (**T-RO**) [CPS Security]