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 uses concepts from optimal control, conformal mapping, reachability analysis, machine learning, motion planning, and transfer learning to develop **learning-based control** and **safe planning** techniques.

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 — *Charlottesville, VA*
Ph.D., Candidate, Computer Engineering — *Aug.2017 – Dec. 2023 (Expected)*

Beijing Institute of Technology — *Beijing, China*
B.S., in Automation — *Aug. 2013 – July, 2017*

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

Skills

Proficient in **C++**, **MATLAB**, **Python**, **ROS**, **Gazebo**, **LINUX**
Proficient in **Assembling**, **Developing**, **Operating** and **Maintaining** a variety of robotic systems:

- **UGV**: Boston Dynamics Spot (Robotic dog), Clearpath Jackal, Clearpath Ridgeback, Turtlebot 2/3, ROSBot, etc.,
- **UAV**: AscTec Hummingbird, AscTec Pelican, Crazyflie, DJI M300RTK, DJI Mavic Enterprise, Parrot Bebop, etc.,
- **Sensors**: RGB-D Camera, Thermal Camera, 2/3D LiDAR, GPS etc.,
- **Other platforms**: Phidgets, Raspberry Pi, DJI OSDK, Variety of Simulators, etc.,

SELECTED RESEARCH

University of Virginia, Link Lab — *Charlottesville, VA*
Graduate Research Assistant — *Jan. 2018 - Now*

Epistemic Prediction and Planning for Multi-Robot Teams in Communication Restricted Environments

Proposed a novel **epistemic planning** framework for distributed **consensus-based** planning to solve generalized **assignment problems** and **coverage problems**.

- Proposed an **epistemic planning** using **dynamic epistemic logic**, formalizing beliefs, and knowledge for robot control.
- Presented a generalized **task assignment** and **artificial potential field**-based model for **belief propagation** and coverage of an environment considering **connectivity constraints** and team dynamics.

Bridging the Gap for Sim2Real and Real2Real Transfer Learning

Developed a conformal mapping-based transfer framework that rapidly adapts the control and path planning policy between systems with different dynamics.

- Demonstrated a novel transfer framework that conformally maps the control input domains between two different systems bypassing accurate model learning.
- The framework is validated over different controllers (PID, **MPC**) and planning methods (Motion Primitives Planning).

Sampling-based Next-Best-View path planning for UAV autonomous inspection

Optimized path planner for UAV inspecting tasks in partially known environments while minimizing the inspecting points.

- Designed the **spatial information gain** to optimize inspecting points in the presence of unknown obstacles and occlusion.
- Utilized Particle Swarm Optimization (**PSO**) for optimizing waypoint navigation.
- Perception estimation for inspecting at **runtime** by combining **raytracing**, **Lidar**, and **Gaussian Process** (**GP**).
- Validated with experiments on both the unmanned aerial vehicle and the unmanned ground vehicle.

Meta-Learning-based Proactive Online Planning for Autonomous Vehicles under Degraded Conditions
Developed assured runtime monitoring and replanning techniques for systems under disturbances.

- Proposed a **Meta-Learning** based framework to predict the system's future states and state uncertainties under unforeseen actuator faults.
- Developed a runtime predicting model monitoring and validation method with Model-Agnostic Meta-Learning (**MAML**).
- Developed a waypoint-sampling-based path replanning method for safety assurance.

Exploiting Airflow Dynamics for Efficient Autonomous UAV Motion Planning and Enhancing Safety
Leveraged the airflow dynamic changes to improve the safety and energy consumption of the quadrotors.

- Developed a novel testbed and characterized the ground and the ceiling effects for quadrotors.
- Developed a **sensor-less** surface detection and landing method for enhanced safety in quadrotor operation.
- Proposed an **energy-efficient path planning** method by leveraging airflow dynamics for up to 13% energy reduction.

SELECTED PUBLICATION

- **Next-Best-View-based Task and Motion Planning for Autonomous Photography & Inspection**
  S. Gao, L. Bramblett, and N. Bezzo, in 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (**IROS 23'**) Workshop on Task and Motion Planning
- **Meta-Learning-based Proactive Online Planning for UAVs under Degraded Conditions**
  S. Gao, E. Yel, and N. Bezzo, in IEEE Robotics and Automation Letters (**RA-L**)
- **A Conformal Mapping-based Framework for Robot-to-Robot and Sim-to-Real Transfer Learning**
  S. Gao, and N. Bezzo, in 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (**IROS 21'**)
- **Exploiting ground and ceiling effects on autonomous UAV motion planning**
  S. Gao, C. Di Franco, D. Carter, D. Quinn, and N. Bezzo, in IEEE 2019 International Conference on Unmanned Aircraft Systems (**ICUAS 19'**)
- **Epistemic Prediction and Planning with Implicit Coordination for Multi-Robot Teams in Communication Restricted Environments**
  L. Bramblett, ***S. Gao***, and N. Bezzo, in IEEE 2023 International Conference on Robotics and Automation (**ICRA 23'**)
- **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**)
- **A data-driven framework for proactive intention-aware motion planning of a robot in a human environment**
  R. Peddi, C. Di Franco, ***S. Gao***, and N. Bezzo, in 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (**IROS 20'**)
- **Model-based randomness monitor for stealthy sensor attacks**
  P.J. Bonczek, ***S. Gao***, N. Bezzo, in IEEE 2020 American Control Conference (**ACC 20'**)
- **Sampling-Based Next-Best-View planning for Autonomous Aerial Inspection**
  S. Gao, L. Bramblett, and N. Bezzo, under review for IEEE Robotics and Automation Letters (**RA-L**)
- **Smooth Transfer: A Conformal-Mapping-Based Transfer Learning Framework in Receding Horizon Manner**
  S. Gao, and N. Bezzo, under review for Journal of Intelligent and Robotic Systems (**JINT**)

PRESENTATIONS AND TALKS

- **Oral Presentations**, **21**', **22**', **23**' IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
- **Oral Presentations**, IEEE 2019 International Conference on Unmanned Aircraft Systems (ICUAS)
- **Advisement**, ECE Undergraduate Student Capstone **19**', **20**', **21**
- **2nd Place Presenter**, ECE Student Research Poster Session 2019
- **Finalist**, UVA Engineering Research Innovation Award (RIA) 2019
- **Graduate Teaching Assistant**, Autonomous Mobile Robot 19', 20', 21', 22', 23'