SONGQUN GAO

+852 55649164 | sqgao@mae.cuhk.edu.hk

The Chinese University of Hong Kong, Hong Kong S.A.R., P.R. China

Research Interests

- Topics related to unmanned underwater vehicles (UUVs);
- Topics related to manipulators and mobile manipulators.

Education

University of Science and Technology of China (USTC) Sep 2016 – Jul 2020

Bachelor of Engineering, Department of Automation

- Elite Program for Artificial Intelligence (17% acceptance rate)
- Major: Automation Minor: Artificial Intelligence
- GPA: 3.41 / 4.3
- Selected Courses: Intelligent Robot (91/100), Robot design and manufacture (A), Computer Programming (93/100) Data Structure and Algorithm (89/100), Introduction to Pattern Recognition (92/100).

The Chinese University of Hong Kong (CUHK) Sep 2020 – Present

Ph.D. candidate, Department of Mechanical and Automation Engineering

- Advisor: Prof. Ben M. Chen
- Major: Mechanical and Automation Engineering
- Topic: Development of Lightweight Underwater Unmanned Vehicle Sea-U-Dragon
- Research focus: **Robot-Environment Interaction (REI) in Dynamic Environments, Mechatronics**

Research Experiences

Robot-environment interaction of a light-weight UUV Sea-U-Dragon Sep 2020 – Present

Advisor: Prof. Ben M. Chen, Prof. Qinyuan Ren (Zhejiang University)

- Developed a lightweight UUV called Sea-U-Dragon and the UUV is equipped with a flexible end effector to perform accurate tasks.
- The dynamic model of Sea-U-Dragon based on first principles is derived, and system identification experiments are conducted to identify the parameters of Sea-U-Dragon.
- To operate accurate motion/force tracking in underwater environments, a UDE-based dynamic motion/force controller is implemented.
- The unknown environment is modeled as a damper-spring model. The environment parameters consist of stiffness, damping, and the position of the environment.
- Incorporating the dynamics of the UUV, an augmented EKF is adopted to estimate environmental parameters online. The controller is then optimized based on the obtained environmental parameters.

UDE-based dynamic motion/force control of mobile manipulators Sep 2022 – Sep 2023

Advisor: Prof. Ben M. Chen, Prof. Qinyuan Ren

- Developed the mobile manipulator platform with an Atien TT15 mobile base and a Rokae SR3 manipulator.
- A novel dynamic model of the manipulator on the mobile base is proposed by incorporating the base kinematic information into the manipulator dynamics.

- Embedding our model, a UDE-based dynamic motion/force controller of the manipulator is proposed to improve the dynamic performance of the robot-environment interaction system. The feedforward control law is applied to predict base-induced uncertainties, and UDE compensates for other unmodeled uncertainties.
- The interaction behaviours with the unknown environments are learnt through reinforcement learning. Simulation validates the effectiveness of the RL-based method.

Development of Hybrid Aerial-Aquatic Vehicle and Unmanned Sea-foil Sep 2020 – Present
Advisor: Prof. Ben M. Chen

- Designed and integrated some key hardware components and sensors.
- Led the derivation of dynamic models of the unmanned Sea-foil.
- Headed the field tests of system identification and engaged the control experiments.

Development of simulation of multi-UAV coordinated transportation Oct 2020 – Oct 2022
Internship at Fundamental Group in IMAV Competition, PengCheng Laboratory
Advisor: Prof. Ben M. Chen

- Built up a string model in Gazebo and then built up three UAVs connected to a payload with PX4 and MAVROS interfaces.
- Realized the simulation of multi-UAV coordinated transportation, where UAVs operate in the offboard mode in XTDrone.

Effective Dynamic Coverage Control for Heterogeneous Driftless Control Affine Systems (Link)
Undergraduate Final Year Project, USTC Jan 2020 – Sep 2020
Advisor: Prof. Zhen Kan

- Robots with general heterogeneous dynamics are considered in the proposed coverage control strategy and the strategy can be extended to many dynamical systems.
- The proposed coverage control strategy ensures the robots dynamically monitor a workspace by making the robot move in the direction of the effective coverage and escape the saddle point until the workspace is completely covered.
- Due to the consideration of limited communication capability, the proposed coverage control strategy ensures that the network connectivity of the robots is maintained throughout the coverage task.

Robot Exploration of Large-Scale Environments (Link) Jul 2019 – Sep 2019
Internship at Unmanned Systems Research Group, CUHK
Advisor: Prof. Ben M. Chen

- A new finite state machine with two states is proposed (zigzag state and travel state) to iteratively derive the robot to accomplish the complete exploration. The zigzag pattern path in zigzag state ensures efficient exploration in every cell.
- Frontier node is introduced to increase the efficiency of the path generated. In travel state, the robot moves to the nearest frontier node, which can shorten the path length generated in the travel state.
- Simulations demonstrate that the algorithm is efficient and robust and outperforms other algorithms (e.g., RH-NBV, ECPP) in aspects of path cost of complete exploration.

Project Experiences

Drone-based Surveillance and Inspection Project at Wo Hop Shek In application
Electrical and Mechanical Services Department (EMSD), HKSAR Government
Student coordinator

- Design the monitoring system based on DJI UAV, including a human detection system and a work detection system.

- Development of the work permit system in Wo Hop Shek region, providing the geofence monitoring system.

Development of an unmanned underwater vehicle for benthic survey, 3d reconstruction, and automatic sampling In application

the Marine Ecology Enhancement Fund (MEEF)

Student coordinator

- Develop a UUV for benthic survey in the western waters of Hong Kong close to the Hong Kong International Airport (HKIA) Third Runway for coral survey and conservation.
- The UUV system includes a mission planner, an underwater vision enhancement system, and an underwater 3D reconstruction system.

Paper & Patents

[1] S. Gao, R. Yan, Z. Zhao, W. Ding, M. Dou, and Ben M. Chen, " Sea-U-Dragon: A Lightweight Unmanned Underwater Vehicle for Robot-Environment Interaction," completed, 2024.

[2] S. Gao, W. Ding, Q. Ren, and Ben M. Chen, "UDE-based Dynamic Motion Force Control of Mobile Manipulators," *ArXiv, abs/2404.00443*, 2024.

[3] S. Gao, R. Yan, Z. Zhao, M. Dou, X. Liu, D. Huang, Q. Ren, and Ben M. Chen, "Dynamic Modeling of a Lightweight Unmanned Underwater Vehicle: Sea-U-Dragon," to be presented at *Chinese Control Conference*, July, 2024.

[4] X. Liu, M. Dou, R. Yan, D. Huang, S. Gao, B. Wang, J. Cui, Q. Ren, L. Dou, Z. Gao, J. Chen and B. M. Chen, TJ-FlyingFish: An unmanned morphable aerial-aquatic vehicle system, Unmanned Systems, in press.

[5] Z. Zhao, Y. Zhai, C. Gao, W. Ding, R. Yan, S. Gao, B. Han, X. Liu, Z. Guo, Ben M. Chen, "Sea-U-Foil: A Hydrofoil Marine Vehicle with Multi-Modal Locomotion," to be presented at *2024 IEEE International Conference on Robotics and Automation (ICRA)*, Yokohama, Japan, May, 2024.

[6] X. Liu, M. Dou, D. Huang, S. Gao, R. Yan, B. Wang, J. Cui, Q. Ren, L. Dou, Z. Gao, J. Chen, B. M. Chen, "TJ-FlyingFish: Design and Implementation of an Aerial-Aquatic Quadrotor with Tiltable Propulsion Units," *2023 IEEE International Conference on Robotics and Automation (ICRA)*, London, United Kingdom, 2023, pp. 7324-7330.

[7] S. Gao and Z. Kan, "Effective Dynamic Coverage Control for Heterogeneous Driftless Control Affine Systems," in *IEEE Control Systems Letters*, vol. 5, no. 6, pp. 2018-2023, Dec. 2021.

[8] S. Gao, Y. Ding, and Ben M. Chen, "A Frontier-Based Coverage Path Planning Algorithm for Robot Exploration in Unknown Environment," *2020 39th Chinese Control Conference (CCC)*, Shenyang, China, 2020, pp. 3920-3925.

[9] Underactuation vacuum chuck paw with multiple grabbing modes. Patent No: CN201810112492.

Honor & Awards

- 2018 Robogame of USTC, the Second Award, Top 16.
- 2017 Scholarship for Outstanding Students (Bronze Award, top 30%).

Skills

Programming Skills: C++, Python, MATLAB.

Software: ROS, Gazebo, PyBullet, Keil, Solidworks.

Personal Interests

Brazilian Jiu Jitsu – Blue belt.