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

Research Interests

- Topics related to Manipulator;
- Topics related to Unmanned underwater vehicle (UUV);
- Human-robot-environment interaction.

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 Underwater Unmanned Vehicle Sea-U-Dragon

Research Experiences

Robot-environment interaction of mobile manipulators   Sep 2023 – Present

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

- The robot-environment interaction effect is modelled as a damper-spring model, and augmented EKF is adopted to estimate environmental parameters.

Development of a light-weight Underwater Unmanned Vehicle Sea-U-Dragon   Sep 2020 – Present

Phd thesis

Advisor: Prof. Ben M. Chen

- Developing a light-weight UUV called Sea-U-Dragon. The maneuverability of the UUV ensures its operation in confined spaces, 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.
- Sea-U-Dragon's maneuverability and ability to execute precise tasks are validated through trajectory following

experiments and water tank cleaning demonstrations.

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

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

- Developed the mobile manipulator platform with 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 dynamic coupling between the mobile base and the manipulator, as well as other unmodeled uncertainties.
- Compared to impedance control (IC) and IC incorporated with our dynamic model and feedforward base information, the proposed control strategy demonstrates excellent proficiency in compensating for dynamic coupling and various unmodeled uncertainties encountered during the movement of the mobile base.

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

- Learnt the signal flow in XTDrone and could operate the offboard control in XTDrone.
- Built up a string model in Gazebo.
- Built up three UAVs connected to a payload with PX4 and MAVROS interfaces.
- Realized the simulation of multi-UAV coordinated transportation.

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 the zigzag state can assure efficient exploration in every cell.
- Frontier node is introduced to increase the efficiency of the path generated. In the 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

Coordinator

- Design the monitoring system based on DJI UAV.
- Development of the work permit system in Wo Hop Shek region, providing the geofence monitoring system.
- AI system development for human detection and work detection.

Development of an unmanned underwater vehicle for benthic survey,   In application

3d reconstruction, and automatic sampling

the Marine Ecology Enhancement Fund (MEEF)

Coordinator

- This project aims to develop a sophisticated Unmanned Underwater Vehicle (UUV) system for intricate underwater inspection and operation to replace traditional manual approaches with higher risks and lower efficiency. Especially, the proposed technology will be utilized to conduct 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 an advanced mission planner for optimal route and task management, an underwater vision enhancement system for improved visibility, and a 3D reconstruction system for detailed mapping of underwater environments.
- Together, these technologies enhance the efficiency and safety of underwater exploration and protection of less monitored coral species. Our existing R&D platforms in these domains have validated the effectiveness and viability of our proposed research plans and methods. The developed platforms can be further optimized and applied in the survey and protection of other endangered marine life.

Paper & Patents

S. Gao, R. Yan, Z. Zhao, M. Dou, Q. Ren, and Ben M. Chen, "Sea-U-Dragon, an underwater unmanned vehicles for confined space applications" completed, 2024.

S. Gao, W. Ding, Q. Ren, and Ben M. Chen, "UDE-based Dynamic Motion Force Control of Mobile Manipulators," completed, 2024.

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.

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.

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.

Underactuation vacuum chuck paw having 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.