

# Chunyang Zhao

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## EDUCATION

### Nanyang Technological University, Singapore

Jan 2019 – Present

#### Ph.D. Robotics & AI (School of EEE)

Jan 2022 – Expected Aug 2026

📖 **Thesis:** A Digital Twin-Based High-Fidelity Low-Bandwidth Teleoperation System for Urban Robotics

Advisors: Prof. Wang Danwei (*IEEE Life Fellow; Fellow, Academy of Engineering Singapore*) & Prof. Cheah Chien Chern

#### M.Sc. Computer Control and Automation

Jun 2019 – Jun 2020

📖 **Thesis:** Multi-Robot Semantic Mapping Based on Deep Learning Framework

Advisor: Prof. Wang Danwei; Co-advisor: Dr. Yue Yufeng (*now Full Professor, BIT*)

#### Exchange Final Year Project in Robotics

Jan 2019 – Jun 2019

📖 **FYP:** Semantic-based Mobile Robot 3D Mapping Using Deep Learning Algorithm

Advisor: Prof. Wang Danwei; Co-advisor: Dr. Yue Yufeng

### Wuhan University, China

Sept 2015 – Jun 2019

#### B.E. Measurement and Control Technology and Instrumentation (School of Electronic Information)

## WORK EXPERIENCE

### Nanyang Technological University, Singapore

Aug 2020 – Present

Research Associate

PI: Prof. Wang Danwei

#### Fire-Scene Emergency Robotics

Nov 2025 – Present

- Building a **multi-agent system integration and communication framework** that unifies robot-mounted and helmet-worn SLAM systems (thermal + 4D radar) with a centralized command center for fire-scene emergency response.

#### Autonomous Systems & Teleoperation

Apr 2021 – Oct 2025

- Led full-stack software development of autonomous driving and digital-twin teleoperation systems, from algorithm design through simulation validation to field deployment.
- Proposed a **digital twin teleoperation paradigm** replacing video streaming with kbps-level scene-model transmission, validated on **AgileX Hunter 2.0** and **Clearpath Husky** across day/night scenarios.
- Led **Autoware Universe** stack customization and deployment for **Hunter 2.0** and the **4-ton articulated Bucher Municipal Sweeper**, achieving autonomous field demo at **13 km/h**.

#### Multi-Robot Mapping

Aug 2020 – Apr 2021

- Developed a **multi-Husky-UGV and UAV collaborative semantic mapping system** in unstructured environments with heterogeneous sensor fusion.

### Temasek Laboratories, National University of Singapore

Mar 2019 – Jul 2019

Research Intern

PI: Dr. Gao Zhi (*now Full Professor, WHU*)

- Evaluated and benchmarked stereo-inertial odometry pipelines; performed multi-sensor calibration for visual-inertial SLAM systems.

## TECHNICAL SKILLS

### </> Programming:

C/C++ Python

### ⚙️ Robotics Stack:

ROS/ROS2 Autoware Universe Lanelet2 Zenoh ZeroMQ Foxglove PlotJuggler

### 🖥️ Simulation:

UE 4/5 Gazebo CARLA AWSIM

### ⚡ ML & Inference:

PyTorch ONNX TensorRT MMDeploy

### 👁️ 3D & Perception:

PCL OpenCV Open3D MMDet3D MMSeg OpenPCDet

### 🔧 Engineering:

Git CMake GDB Linux Bash/Zsh Zellij Docker Anaconda uv

## SELECTED PROJECTS

### 🚗 AESV (Autonomous Environmental Service Vehicles)

Apr 2024 – Jul 2025

- Served as **software leader and primary contributor**, building an Autoware Universe-based autonomy stack for the **AgileX Hunter 2.0** and a **4-ton articulated Bucher Municipal Sweeper**.

- Customized and deployed Autoware Universe core stack on both platforms: **HD-map pipeline**, **localization** (NDT scan matching + EKF fusion), **LiDAR perception** (TensorRT-accelerated LiDAR CenterPoint + muSSP-based min-cost-max-flow data association + EKF tracking), **prediction** (map-based trajectory prediction), and **planning**; supported control bring-up.
  - Developed platform-specific **sensor-model** and **vehicle-interface** packages to integrate sensor preprocessing pipelines and chassis communication into Autoware across both platforms.
  - Built a multi-level communication bridge (**ros1\_bridge** + **Fkie Multi Master** + **ZeroMQ**) to link the Autoware ROS2 stack with ROS1 drive-by-wire interfaces of the Sweeper across separate computers.
  - Developed a **vehicle-command conversion layer** and supported **accel/brake map calibration** to integrate the Autoware control module with the Sweeper.
  - Led the development of a **digital-twin based autonomous simulation system** in a customized CARLA simulator (UE4-based) for NTU Carpark P and Cetran, combining static site twins with dynamic scenario simulation (vehicles, pedestrians, and weather) for validation before field testing.
  - Established a staged **testing workflow** from simulation to field tests and from **Hunter 2.0** to **Sweeper** rollout, using each cycle to refine stack settings and interfaces.
  - Delivered **autonomous field demos** as the main software contributor: **Hunter 2.0** at NTU Carpark P and **Sweeper** at Cetran; during autonomous demo runs, the Sweeper reached up to **13 km/h**.
  - Conducted preliminary research on **universal targetless extrinsic auto-calibration** (LiDAR-camera, LiDAR-thermal) and **deep-learning-based curb segmentation** (Cylinder3D, MMDetection3D) for future extension.
- 🔗 **Beyond Video Streaming: Digital Twin Teleoperation at Kbps** Mar 2022 – Sep 2024

- Proposed a **digital twin teleoperation paradigm (Persistent-Transient Environment Model)** to replace bandwidth-intensive video streaming: the remote environment is pre-built as a 3D digital twin and stored at the operator's platform, so that only the robot's pose and detected dynamic obstacles need to be transmitted in real time (~500 Kbps vs. several Mbps for video), giving the operator **360° freely adjustable viewpoints** independent of camera placement and **robust day/night operation** independent of lighting conditions.
- **Tele-Twin (Gen 1)**: designed and built an end-to-end mesh-based teleoperation system. *Offline*: constructed large-scale **mesh digital twins** by building a static LiDAR point cloud map (semantic segmentation filters out movable objects such as vehicles and pedestrians) and fusing it with **photogrammetry-based 3D mesh reconstruction**. *Robot side*: ran **LiDAR-IMU localization** (NDT scan matching + UKF) for vehicle pose estimation, and **3D object detection/tracking** (TensorRT CenterPoint + muSSP + EKF, <100 ms per frame) to identify surrounding dynamic obstacles. *Communication*: transmitted only compact pose and obstacle data via **ros1\_bridge** + **TCP tunnel** across separate ROS1/ROS2 networks. *Operator side*: rendered the pre-loaded mesh twin with live robot and obstacle overlays in **Unreal Engine 5**, providing the operator interactive 360° views and synchronized motion feedback on a 3-DOF motion platform.
- **Tele-GS (Gen 2)**: upgraded to a photorealistic teleoperation system by replacing the mesh twin with **3D Gaussian Splatting (3DGS)**. *Offline*: proposed a **LiDAR map-initialized large-scale 3DGS construction pipeline**: a semantic LiDAR SLAM point cloud map provides accurate geometric priors for 3DGS training, yielding photorealistic scene representation with **59% less GPU memory** and **84% less storage** than mesh-based rendering. The same point cloud map also serves as the re-localization reference during online operation. *Robot side*: upgraded localization to NDT + EKF with a vehicle dynamics model; retained the real-time 3D detection/tracking pipeline. *Communication*: redesigned with **Zenoh** + **ZeroMQ** middleware bridging the ROS2 robot, UE5 renderer, and motion simulator. *Operator side*: rendered the 3DGS scene with **Unreal Engine 5**, achieving near-photo-realistic 360° telepresence.
- Designed and built a **portable multi-modal scanning device** (LiDAR + IMU + panoramic camera with hardware-level PPS synchronization), and developed a **digital twin creation pipeline** supporting large-scale **3DGS**, **mesh**, and **color point cloud** reconstruction, providing high-fidelity site-level digital twins for both generations.
- Validated both generations on **real robotic platforms** (Hunter 2.0, Husky) across day/night carpark and public road scenarios, confirming illumination-invariant 360° telepresence at ~500 Kbps bandwidth.

🏆 **Amex Dreamer (1st Place, AMEX GenAI Hackathon 2025, American Express Singapore)** Oct 2025

- Designed an **MCP-based orchestration flow** to transform credit-card transactions into **personalized memory videos**, coordinating profile upload, transaction query, context enrichment, prompt generation, and video generation.
- Implemented a **demo text-to-image-to-video workflow** with **Gemini 2.5 Flash Image (Nano Banana)** and **Wan 2.1**: transaction records → narrative prompts → image moments → short memory clips.
- Used generated image keyframes as **anchor inputs to Wan 2.1** for image-to-video handoff, preserving character and scene consistency in demo clips.

## PUBLICATIONS

📊 17 publications | 2 first-author IROS | 3 journal • 14 conference

🔗 IEEE Xplore

### 📖 Journal Articles (3)

2023 Yuanzhe Wang, **Chunyang Zhao**, Jiahao Liang, Mingxing Wen, Yufeng Yue, Danwei Wang. *Integrated Localization and Planning for Cruise Control of UGV Platoons in Infrastructure-Free Environments*. **T-ITS**

UGV Platoon Cruise Control | Infrastructure-Free Localization | NLOS Trajectory Planning

- 2021 Yufeng Yue, Mingxing Wen, **Chunyang Zhao**, Yuanzhe Wang, Danwei Wang. *COSEM: Collaborative Semantic Map Matching Framework for Autonomous Robots*. **T-IE**  
 Multi-Robot Relative Localization Semantic Map Matching EM Data Association
- 2020 Yufeng Yue, **Chunyang Zhao**, Zhenyu Wu, Chule Yang, Yuanzhe Wang, Danwei Wang. *Collaborative Semantic Understanding and Mapping Framework for Autonomous Systems*. **T-Mech**  
 Collaborative Probabilistic Semantic Mapping Heterogeneous Sensor Fusion UAV-UGV Distributed Mapping
- 👤 **Conference Papers (14)**
- 2025 ★ **Chunyang Zhao**, Zeyu Zhou, Haoran Liu, Dogan Kircali, Huan Yang, Chang Boon Low, Yuanzhe Wang, Danwei Wang. *Tele-GS: 3D Gaussian Scene Representation for Low-Bandwidth Teleoperation*. **IROS Oral** [\[Paper\]](#)  
 Low-Bandwidth Teleoperation LiDAR-Fused 3DGS Kbps-Level Telepresence
- 2024 ★ **Chunyang Zhao**, Zeyu Zhou, Haoran Liu, Dogan Kircali, Guoyi Chi, Hongming Shen, Yuanzhe Wang, Danwei Wang. *Towards Kbps-level Vehicle Teleoperation via Persistent-Transient Environment Modelling*. **IROS Oral** [\[Paper\]](#) [\[Demo\]](#)  
 Non-Video Teleoperation Persistent-Transient Environment Model Digital-Twin Telepresence
- Huan Yang, Guoqiang Liu, **Chunyang Zhao**, Mingxing Wen, Yuanzhe Wang. *Real-Time GNSS Spoofing Detection for Autonomous Vehicles: An Attention-Based Autoencoder Approach*. **ICARCV**  
 GNSS Spoofing Detection IMU-LiDAR-GNSS Cross-Checking Attention Autoencoder
- Yichen Zhou, Mingxing Wen, Xun Chen, **Chunyang Zhao**, Jiajie Guo, Jun Zhang, Yufeng Yue, Yingchong Ma. *Towards Safe and Efficient Last-Mile Delivery: A Multi-Modal Socially Aware Navigation Framework for Autonomous Robots on Pedestrian-Crowded Sidewalks*. **CIS-RAM**  
 Sidewalk Delivery Robot 3D Pedestrian Detection & Motion Prediction Social-Force Planning
- Zhenyu Wu, Wei Wang, **Chunyang Zhao**, Yufeng Yue, Jun Zhang, Hongming Shen, Danwei Wang. *MM4MM: Map Matching Framework for Multi-Session Mapping in Ambiguous Environments*. **ICRA**  
 Multi-Session Map Merging Magnetic-Field Place Recognition Perceptually-Degraded Environments
- 2023 Yuanzhe Wang, **Chunyang Zhao**, Haoyi Wang, Jun Zhang, Danwei Wang. *Secure Localization of Autonomous Articulated Vehicles: Attack Detection and Recovery*. **ITSC**  
 Articulated Vehicle Localization Multi-Sensor Cross-Checking DoS/Spoofing Recovery
- Jun Zhang, Huayang Zhuge, Yiyao Liu, Guohao Peng, Zhenyu Wu, Haoyuan Zhang, Qiyang Lyu, Heshan Li, **Chunyang Zhao**, Dogan Kircali, Sanat Mharolkar, Xun Yang, Su Yi, Yuanzhe Wang, Danwei Wang. *NTU4DRadLM: 4D Radar-Centric Multi-Modal Dataset for Localization and Mapping*. **ITSC**  
 4D Radar-Centric SLAM Dataset Thermal-LiDAR-Camera Six-Sensor Suite Adverse-Weather Robustness
- 2022 Mingxing Wen, Yunxiang Dai, Tairan Chen, **Chunyang Zhao**, Jun Zhang, Danwei Wang. *A Robust Sidewalk Navigation Method for Mobile Robots Based on Sparse Semantic Point Cloud*. **IROS**  
 LiDAR-Only Sidewalk Navigation Point-Wise Semantic Segmentation Day-Night Robustness
- Yufeng Yue, **Chunyang Zhao**, Yuanzhe Wang, Yi Yang, Danwei Wang. *Aerial-Ground Robots Collaborative 3D Mapping in GNSS-Denied Environments*. **ICRA**  
 UAV-UGV Collaborative Mapping GNSS-Denied Environments Multi-Resolution Map Fusion
- Shutong Jin, Zhenyu Wu, **Chunyang Zhao**, Jun Zhang, Guohao Peng, Danwei Wang. *SectionKey: 3-D Semantic Point Cloud Descriptor for Place Recognition*. **IROS**  
 LiDAR Place Recognition Semantic-Geometric Descriptor Viewpoint-Invariant Loop Closure
- 2020 Yufeng Yue, **Chunyang Zhao**, Mingxing Wen, Zhenyu Wu, Danwei Wang. *Collaborative Semantic Perception and Relative Localization Based on Map Matching*. **IROS**  
 Multi-Robot Relative Localization Probabilistic Semantic Association EM Map Matching
- Yufeng Yue, **Chunyang Zhao**, Ruilin Li, Chule Yang, Jun Zhang, Mingxing Wen, Yuanzhe Wang, Danwei Wang. *A Hierarchical Framework for Collaborative Probabilistic Semantic Mapping*. **ICRA**  
 Hierarchical Collaborative Mapping Distributed Bayesian Fusion EM Voxel Association
- 2019 Yufeng Yue, Ruilin Li, **Chunyang Zhao**, Chule Yang, Jun Zhang, Mingxing Wen, Guohao Peng, Zhenyu Wu, Danwei Wang. *Probabilistic 3D Semantic Map Fusion Based on Bayesian Rule*. **CIS-RAM**  
 Multi-Robot Semantic Map Fusion Bayesian Label & Occupancy Update Decentralized Map Sharing
- Ji Hong, Zhi Gao, Tiancan Mei, Yifan Li, **Chunyang Zhao**. *UAV-based Traffic Flow Estimation and Analysis*. **ICCA**  
 UAV Traffic Monitoring Spatiotemporal Vehicle Detection Optical-Flow Classification

## LANGUAGES

Chinese (Native) • English (Fluent)