

Zhirui Dai

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EDUCATION

University of California San Diego	San Diego, CA, USA
<i>Ph.D. in Electrical and Computer Engineering</i>	<i>01/2022 - Current (Expected 06/2027)</i>
University of California San Diego	San Diego, CA, USA
<i>M.S. in Electrical and Computer Engineering</i>	<i>09/2019 - 06/2021</i>
Fudan University	Shanghai, China
<i>B.S. in Physics</i>	<i>09/2015 - 06/2019</i>

TECHNICAL SKILLS & OPEN SOURCE CONTRIBUTIONS

Programming Languages: C++, CUDA, Python, C, MATLAB, Java, Swift

Libraries and Tools: PyTorch, ROS, OpenCV, Open3D, Docker, Kubernetes, LangChain, ManiSkill

Made Open Source Contributions to: [PyTorch](#), [Open3D](#), [PointCloudLibrary](#), [pybind11](#)

RESEARCH

I am passionate about enabling autonomous robots to safely navigate and interact in complex environments. My research focuses on 3D scene representation learning, vision-language models for robotics, and robot task planning with large language models. I leverage CUDA, C++, Python etc. to develop algorithms that allow robots to perceive, reason, and act in the real world.

Research Assistant, UCSD Existential Robotics Lab

San Diego, CA, USA

Advisor: Prof. Nikolay Atanasov

01/2022 - Current

• Vision-Language Models for 3D Scene Understanding & Manipulation [RSS 2025, ICRA 2026]

- Architected [SBP](#), an incremental 3D language-feature mapping framework that provides **spatiotemporal memory** for mobile manipulators in unseen environments.
- Implemented **hierarchical hash-grid maps** with PyTorch to encode high-dimensional vision-language features from **2D VLMs** (e.g., CLIP, DINO) into a lower-dimensional latent space and a **cross-scene generalized decoder** to reconstruct the original features.
- Developed a **transformer-based manipulation policy** conditioned on the 3D language-feature map, outperforming baselines by **10% in in-domain and 10-20% in out-of-domain scenes**.
- Engineered data pipelines in **ManiSkill-HAB** to synthesize large-scale multi-modal datasets (RGB-D, semantic labels, task descriptions) for training the decoder and the manipulation policy.

• Neural Signed Directional Distance Functions (SDDF) for 3D Reconstruction [RSS 2025, TPAMI_{minor revision}]

- Introduced [SDDF](#), a novel 3D representation enabling single-pass computation for occlusion reasoning and collision checking.
- Designed a hybrid neural model combining ellipsoidal priors with neural residuals to learn scene-level SDDF from point clouds, achieving **SOTA reconstruction accuracy** on Replica dataset.
- Engineered custom [CUDA kernels](#) for ellipsoidal SDDF computation, indexed pose transformations and indexed linear layer, achieving up to **600x speedups** and **50-90% GPU RAM savings** compared to PyTorch implementations.
- Deployed the model on aerial platforms to demonstrate real-time sensor view coverage maximization and collision avoidance.

• Real-time Signed Distance Function (SDF) Learning [IJRR, RA-L_{under review}, IROS 2026_{under review}]

- Proposed $\nabla\text{-SDF}$, a neural method for globally accurate, real-time SDF learning from LiDAR/RGB-D, achieving **30% lower prediction error** than SOTA while maintaining real-time speed (12fps).
- Open-sourced the first [semi-sparse octree library](#) in C++ with **custom CUDA kernels**, accelerating voxel indexing by up to **550x** and Morton code computation by up to **13x**.
- Developed [Kernel-SDF](#), a C++ kernel regression framework for real-time SDF learning with **uncertainty quantification**, featuring full Python and **ROS** interfaces.

• Large Language Model (LLM) for Robotic Task Planning [ICRA 2024, IROS 2025]

- Built an [optimal scene graph planner](#) utilizing [LangChain](#) to translate natural language into LTL specifications.
- Proposed a scene graph planning algorithm that leverages consistent LTL heuristics and LLM guidance to achieve **1600x speedup** over AMRA* while guaranteeing plan optimality.
- Proposed [LTLCodeGen](#), utilizing prompt engineering to generate **100% syntactically correct** LTL specifications, outperforming fine-tuned baselines (e.g., BART-large).

Research Assistant, UCSD Statistical Visual Computing Lab

San Diego, CA, USA

Advisor: Prof. Nuno Vasconcelos

06/2020 - 08/2021

• Social Distance Monitoring from Surveillance Videos [ICCV 2021]

- Developed [BEV-Net](#), a real-time social distance monitoring system (for COVID-19 pandemic) utilizing a novel **Bird's-Eye-View (BEV) projection layer** to map image features to BEV space.
- Implemented a calibration-free approach by recovering camera pose (height and pitch) via human keypoint detection and human heights.
- Achieved **30% lower error** in distance estimation and **2x higher IoU** for risk zone detection compared to SOTA methods.

PUBLICATIONS

- Sunghwan Kim, Woojeh Chung, Zhirui Dai, Dwait Bhatt, Arth Shukla, Hao Su, Yulun Tian, Nikolay Atanasov. “**Seeing the Bigger Picture: 3D Latent Mapping for Mobile Manipulation Policy Learning.**” In IEEE International Conference on Robotics and Automation (ICRA), 2026. [Paper](#) [Project](#)
- Zhirui Dai, Qihao Qian, Tianxing Fan, Nikolay Atanasov. “ **∇ -SDF: Learning Euclidean Signed Distance Functions Online with Gradient-Augmented Octree Interpolation and Neural Residual.**” Submitted to IEEE International Conference on Intelligent Robots and Systems (IROS), 2026, under review. [Paper](#) [Project](#)
- Zhirui Dai, Tianxing Fan, Mani Amani, Jaemin Seo, Ki Myung Brian Lee, Hyondong Oh, Nikolay Atanasov. “**Real-Time Learning of Signed Distance Function via Kernel Regression with Uncertainty Quantification.**” Submitted to IEEE Robotics and Automation Letters (RA-L), 2026, under review. [Paper](#) [Project](#)
- Zhirui Dai, Hojoon Shin, Yulun Tian, Ki Myung Brian Lee, Nikolay Atanasov. “**Learning Scene-Level Signed Directional Distance Function with Ellipsoidal Priors and Neural Residuals.**” Submitted to IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI), 2025, minor revision. [Paper](#) [Project](#)
- Zhirui Dai, Hojoon Shin, Yulun Tian, Ki Myung Brian Lee, Nikolay Atanasov. “**Learning Scene-Level Signed Directional Distance Function for Aerial Autonomy.**” In Workshop on Leveraging Implicit Methods for Aerial Autonomy at Robotics: Science and Systems (RSS), 2025. [Paper](#) [Project](#) [Best Paper Award]
- Sunghwan Kim, Woojeh Chung, Yulun Tian, Zhirui Dai, Arth Shukla, Hao Su, Nikolay Atanasov. “**Seeing the Bigger Picture: 3D Latent Mapping for Mobile Manipulation Policy Learning.**” In Workshop on Mobile Manipulation and Workshop on Learned Robot Representations at Robotics: Science and Systems (RSS), 2025. [Paper](#) [Best Paper Nonomination]
- Behrad Rabiei, Mahesh Kumar, Zhirui Dai, Surya Lakshmi Subba Rao Pilla, Qiyue Dong, Nikolay Atanasov. “**LTLCodeGen: Code Generation of Syntactically Correct Temporal Logic for Robot Task Planning.**” In IEEE International Conference on Intelligent Robots and Systems (IROS), 2025. [Paper](#) [Project](#)
- Zhirui Dai, Arash Asgharivaskasi, Thai Duong, Shusen Lin, Maria-Elizabeth Tzes, George Pappas, and Nikolay Atanasov. “**Optimal Scene Graph Planning with Large Language Model Guidance.**” In IEEE International Conference on Robotics and Automation (ICRA), 2024. [Paper](#) [Project](#)
- Kehan Long, Yinzhuang Yi, Zhirui Dai, Sylvia Herbert, Jorge Cortés, Nikolay Atanasov. “**Sensor-Based Distributionally Robust Control for Safe Robot Navigation in Dynamic Environments.**” In The International Journal of Robotics Research (IJRR), 2024. [Paper](#) [Project](#)
- Ki Myung Brian Lee, Zhirui Dai, Cedric Le Gentil, Lan Wu, Nikolay Atanasov, and Teresa Vidal-Calleja. “**Safe Bubble Cover for Motion Planning on Distance Fields.**” arXiv preprint arXiv:2408.13377 (2024).
- Zhirui Dai, Yuepeng Jiang, Yi Li, Bo Liu, Antoni B. Chan, and Nuno Vasconcelos. “**BEV-Net: Assessing Social Distancing Compliance By Joint People Localization and Geometric Reasoning.**” In IEEE/CVF International Conference on Computer Vision (ICCV), 2021. [Paper](#)

WORK EXPERIENCE

Research Internship — VR/AR Systems & Deep Learning

XCOM Labs Inc., CA, USA

08/2021 - 12/2021

- Engineered a neural pose prediction algorithm for multi-user VR/AR remote rendering systems, significantly minimizing motion-to-photon latency.
- Designed and trained a neural network that achieves **90% lower error** in trajectory prediction compared to the default OpenVR baseline.
- Curated a proprietary 6-DoF dataset for XR head & hand pose forecasting to benchmark predictive models.

Software Development Internship — SoC Software Development

Camel Microelectronics Inc., CA, USA

01/2018 - 06/2019

- Architected CamelStudioX, a comprehensive IDE for low-power SoC software development, deployed to educational and commercial users. [\[Code\]](#)
- Developed critical embedded infrastructure: **Hardware Abstraction Layers (HAL)**, soft-float libraries, cross-compiler toolchains, and ELF analysis tools. [\[Code\]](#)
- Collaborated with hardware engineers on SoC validation, developing software patches to resolve hardware-level logic issues (hardware hotfixes).

SERVICES

Teaching Assistant, [ECE276B: Planning & Learning in Robotics](#)

04/2024 - 06/2024

Teaching Assistant, [ECE276B: Planning & Learning in Robotics](#)

04/2023 - 06/2023

Mentor, [ENLACE Summer Research Program](#)

07/2022 - 08/2022

Mentor, [ECE Summer Research Internship Program \(SRIP\)](#)

07/2022 - 08/2022

Mentor, [Summer Training Academy for Research Success \(STARS\)](#)

07/2022 - 08/2022

Mentor, [Guided Engineering Apprenticeship in Research \(GEAR\)](#)

09/2021 - 07/2022

AWARDS & HONORS

Electrical and Computer Engineering Department Fellowship

2022

Outstanding Graduate of Fudan University

2019