

# QIJUN LIAO

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## EDUCATION BACKGROUND

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**University of Science and Technology Beijing (USTB)**

*Sep. 2024 – Present*

M.E. in Vehicle Engineering, School of Mechanical Engineering

*Beijing, China*

Cumulative GPA: **88.1/100** (Top 20% in Major)

**Awards:** Second-Class Graduate Scholarship (2025), Merit Graduate Student (2025).

**University of Science and Technology Beijing (USTB)**

*Sep. 2020 – June 2024*

B.E. in Vehicle Engineering, School of Mechanical Engineering

*Beijing, China*

Cumulative GPA: **87.1/100** (Top 20% in Major, Waived from admission test for M.E. due to academic excellence).

**Awards:** Merit Student (2022, 2023), Outstanding Graduates (2024).

## PUBLICATIONS

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[1] **Qijun Liao\***, Jue Yang, “**Response-Aware Risk-Constrained Control Barrier Function With Application to Vehicles**”, Under review in *Automatica*. \*Corresponding Author.

[2] **Qijun Liao**, Jue Yang\*, Yiting Kang, Xinxin Zhao, Yong Zhang, Mingan Zhao, “**Hybrid Energy-Aware Reward Shaping: A Unified Lightweight Physics-Guided Methodology for Policy Optimization**”, Required Reviews Completed in *Neurocomputing*. \*Corresponding Author. <https://arxiv.org/abs/2603.11600>

[3] **Qijun Liao**, Jue Yang\*, Subhash Rakheja, Yiting Kang, Yumeng Yao, Yuming Yin, “**Wheel Dynamic Load Estimation Method Based on Gas Pressure of Hydro-pneumatic Suspension**”, Under review in *Vehicle System Dynamics*. \*Corresponding Author. <https://arxiv.org/abs/2603.14242>

## RESEARCH EXPERIENCE

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**DD-SRad: Decoupled Dynamic Spherical Radial Squashing**

*Oct. 2025 – Present*

Senior Author | *Targeting Engineering Applications of Artificial Intelligence*

*In Preparation*

- **Topological Extension to Differential Action Space:** Extended the SRad geometric framework to the differential action space, enabling hard enforcement of actuator slew-rate limits  $|a_t^i - a_{t-1}^i| \leq \delta^i$  within the policy parameterization layer. The constraint is guaranteed to hold with probability 1 for all dimensions simultaneously, without post-hoc clipping or hierarchical filtering.
- **Dimension-wise Decoupled Effective Radius:** Designed a per-dimension independent effective radius  $R_{\text{eff}}^i$  determined solely by each dimension’s own state–boundary distance and rate limit  $\delta^i$ , breaking the dimensional coupling in global-radius methods where a single constrained dimension compresses the feasible region of all others — a pathology especially severe in legged robots with differentiated rate limits across hip, thigh, and calf joints.
- **Latent Norm Regularization for Gradient Stability:** Incorporated a fixed-coefficient latent norm penalty  $\lambda_{\text{base}} \mathbb{E}[\|u\|^2]$  into the actor objective to prevent gradient saturation near constraint boundaries. As  $\|u\| \gg 1$ , the per-dimension Jacobian  $\partial a^i / \partial u^i \rightarrow 0^+$ ; the regularization maintains latent actions within the effective gradient region.  $\lambda_{\text{base}}$  constitutes the sole algorithm-level hyperparameter, remaining robust across a wide range without environment-specific tuning.
- **Validation:** Systematic comparison against constrained RL and post-hoc projection baselines under homogeneous/heterogeneous rate constraint configurations; legged locomotion validation on Unitree A1 in Isaac Lab under physically realistic heterogeneous joint actuator limits.

**H-EARS: Unified Lightweight Physics-Guided Policy Optimization**

*May. 2025 – Oct. 2025*

Senior Author | *Submitted to Neurocomputing*

*Required Reviews Completed*

- **Functional Independence:** Proved domain independence through functional analysis, enabling independent optimisation of task objectives and energy efficiency without gradient conflicts; proved by contradiction that unified potential functions cannot simultaneously satisfy both task directivity and energy structure constraints.
- **Mechanical Stability to RL Convergence Translation & Lightweight Modeling:** Proved that energy-based potentials provide informationally richer guidance than sparse task rewards, with convergence acceleration factors proportional to energy gradient magnitude over task reward sparsity; achieved  $O(n)$  complexity via selective dynamics capture, reducing modeling effort from expert-level analytical mechanics to energy-based characterisation — directly extensible to legged systems where full analytical models are prohibitively complex.

- **Hybrid Response-Aware Uncertainty Modeling:** Constructed a hybrid uncertainty model leveraging nominal single-track dynamics for control gradient structure while building stochastic response distributions directly from measurable body signals, mapping model-environment mismatch to response distribution variance — maintaining valid safety boundaries without real-time friction coefficient identification.
- **CVaR-Based Tail Risk Reformulation of CBF:** Reformulated the deterministic CBF condition into a probabilistic constraint over the tail risk of the barrier function derivative distribution, replacing conservative  $L_\infty$  worst-case bounds with CVaR margins; established per-step probabilistic safety bounds showing that enforcing the CVaR constraint implies safety violation probability strictly below risk level  $\beta_{\text{risk}}$ .
- **Bayesian Online Covariance Adaptation & Validation:** Inverse Wishart conjugate prior Bayesian update driven by real-time prediction residuals for online noise covariance identification; zero safety boundary violations across all extreme combined-condition scenarios (vs. divergence in deterministic CBF baselines); theoretical per-step violation bound ( $\approx 2\%$  at  $\beta_{\text{risk}} = 0.05$ ) empirically confirmed.

**Wheel Dynamic Load Estimation Method Based on Gas Pressure**

*Jan. 2025 – May. 2025*

Senior Author | *Submitted to Vehicle System Dynamics*

*Under Review*

- **Fluid Inertia-Incorporated Modeling:** Established a comprehensive nonlinear dynamics model explicitly accounting for fluid inertia in gas-oil coupling, where fluid acceleration terms dominate hysteresis under high-frequency excitation (3–8 Hz); derived thermodynamic state equations integrating polytropic gas processes with flow-dependent damping.
- **Pressure-Velocity Uniqueness Mapping Theorem:** Proved bijectivity and differentiability of the mapping  $p \rightarrow v \rightarrow F_z$  under fluid inertia-dominated dynamics, establishing system observability despite measurement dimension reduction — guaranteeing unique load reconstruction from pressure trajectories alone.
- **Experimental Validation:** Bench tests (3–8 Hz sinusoidal): force RMSE <4.2%, velocity RMSE <3.8%, displacement RMSE <4.9%; TruckSim co-simulation (ISO-8608 Class C/D): wheel load RMSE <5% across braking, cornering, and combined maneuvers.

**WORK EXPERIENCE**

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**BAIC BJEV (Beijing Electric Vehicle)**

*Sep. 2025 – Present*

Supply Quality Engineer Intern | *Chassis Engineering Department*

*Beijing, China*

QA of critical chassis sub-systems (Steering, Braking, Suspension); analyzed manufacturing deviation impact on handling performance. Gained hardware-level insight into sensor noise sources and mechanical friction nonlinearities.

**SAIC-GM-Wuling Automobile (SGMW)**

*July 2023 – Aug. 2023*

R&D Intern | *Prototype Testing Department*

*Liuzhou, China*

Analyzed DHT topology and energy management strategies; produced 100+ page technical report on system architecture. Participated in prototype assembly and debugging, bridging theoretical design and manufacturing constraints.

**HONORS**

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**3rd Prize, National**, 14th National Zhou Peiyuan Mechanics Competition (**Highest in USTB History**) *2023*

**2nd Prize, National**, 18th National University Smart Car Competition (National Finals & Northern Division) *2023*

**2nd Prize, Provincial**, National University Physics Competition (**Rank 1st in School of Mechanical Engineering**) *2021*

**1st Prize, University**, USTB Robotics Competition *2021*

**PROFESSIONAL SKILLS**

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**Theory:** Reinforcement Learning, Control Barrier Functions, Lyapunov Stability, Convex & Distributionally Robust Optimization, Sim-to-Real Transfer.

**Programming:** Python, PyTorch, TensorFlow, MATLAB/Simulink, C/C++, LaTeX

**Simulation:** Isaac Lab, TruckSim, CarSim, CARLA

**CAMPUS SERVICE**

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**Head of Academic Department, Student Physics Association, USTB**

*May 2021 – Present*

Designed and delivered training curriculum for the National Zhou Peiyuan Mechanics Competition; conducted specialized lectures on Theoretical Mechanics and dynamics. Organized weekly physics tutoring seminars for undergraduates.