[**en**/zh]

Ke Qiu

Email: ke.qiu@zju.edu.cn | Phone: 86-18605789012
[Homepage] [Google Scholar]

EDUCATION

PhD Candidate | Zhejiang University *September 2022 – July 2027 (expected)*
Control Science and Engineering (Robotics). Supervisor: Profs. Yue Wang, Haojian Lu, Rong Xiong

BEng (Chu Kochen Honors Program) | Zhejiang University *September 2018 – July 2022*
Mechanical Engineering. Minor in Mathematics. GPA 3.96/4.0 (89.84/100), Top 5%

RESEARCH EXPERIENCE

Diffusion-based motion planning for continuum robots

- Formulated motion planning as a path generation problem in the configuration space based on the kinematics model. Trained a diffusion model to learn the inverse mapping from end-effector positions to robot configurations, generating multiple feasible solutions. Trained a diffusion model conditioned on the start and goal configurations to generate smooth intermediate sequences, enabling point-to-point and obstacle-avoidance motion planning in the workspace.

Certifiably global optimal sequential state estimation

- Relaxed the robot state estimation problem in the time domain (or the arc length domain for continuum robots) into a semidefinite programming (SDP) problem using the Cayley map, minimising discrete observation errors subject to boundary constraints. Introduced redundant quadratic constraints to maintain the tightness of relaxation. Solved the resulting SDP using CVX + MOSEK in MATLAB, and verified tightness by the rank of solution matrix.

External force estimation in continuum robots: Closed-form solution, solver and validation [Video]

- Derived a closed-form solution for external force estimation of Kirchhoff rods, and extended it to multisectional tendon-driven continuum robots. Developed a high-order state estimation algorithm with Gaussian process regression, deriving prior mean and kernel functions from stochastic differential equations and fusing discrete noisy measurements from optical fibre Bragg gratings into posterior state distributions. Exploited Gauss–Newton algorithm for solving sparse block tridiagonal systems with O(n) time complexity. Achieved superior estimation accuracy and noise robustness with a 10x speedup in computational efficiency, compared to conventional non-linear solvers (e.g., BFGS). Real-time applications are demonstrated.

Optimal path tracking control in actuator space for tendon-driven continuum robots [Paper] [Code] [Media]

- Based on the inverse kinematics, applied dynamic programming to find the shortest actuator path. Derived optimal time allocation considering actuator constraints. Designed and implemented a control framework, where trajectories planned offline serve as feedforward and inverse Jacobian computed online as real-time feedback, achieving accurate tip pose tracking. Built a multisectional tendon-driven continuum robot hardware and developed the corresponding software (C++) and interface (PLC) to achieve >100 Hz stable asynchronous real-time closed-loop control.

Efficient multi-solution solver for the inverse kinematics of 3-section constant-curvature robots [Paper] [Page]

- Formulated an analytical reduction theory that compresses a highly non-linear system of equations into a one-dimensional problem. Implemented a bounded error approximation to traverse the feasible space with resolution completeness. Developed a solver in MATLAB that eliminates initial values and local minima dependency of traditional non-linear optimisers, achieving 85% reduction in computational latency while providing multiple solutions.

Riemannian optimisation for kinematic closed-chain robots

- Modelled kinematic closed-chain robots with joint constraints as bounded Riemannian submanifolds. Developed numerical tangent-space projection and retraction methods for state updates subject to high-dimensional non-linear equality constraints, and tangent-cone projection for joint-limit equality constraints. Developed a motion generation algorithm for highly redundant closed-chain robots, enabling shape control with improved efficiency and stability.

INTERNSHIP EXPERIENCE

Intern | Zhejiang Humanoid Robot Innovation Center Co. Ltd., Ningbo, China

- Dynamic parameter identification and control optimisation *November 2024 – January 2025*

Developed a regression algorithm to identify latent system parameters, including joint friction and damping coefficient. Designed robust data collection and statistical fitting pipelines. Analysed the frequency spectra of reinforcement learning control signals via FFT, and proposed differentiated lower limb joint bandwidth allocation method, which are shown by experiments to improve walking gait and motor control stability.

- Inverse kinematics analysis of parallel joint mechanisms *July 2024 – August 2024*

Modelled non-linear constrained kinematics for parallel-link ankle and waist joint mechanisms. Developed a numerical solving algorithm and implemented a C++ toolkit that achieves stable computation at 500 Hz. Analysed statics of both serial and parallel mechanisms, solving for the boundaries of permissible workspace and analysing torque transmission, which provide key parameters for reinforcement learning of humanoid robots.

Intern | ABB Corporate Research Center, ABB Engineering (Shanghai) Ltd., Shanghai, China

- High-precision on-site calibration for industrial manipulators *July 2021 – August 2021*

Applied Lie group *SE*(3) and Lie algebra *se*(3) to build geometric models for 6DOF industrial manipulators. Proposed an on-site calibration procedure and algorithm. Constructed a non-linear least-squares problem using canonical blocks, and calibrated latent model parameters with the Levenberg–Marquardt algorithm, reducing absolute positioning errors.

PUBLICATIONS

External force estimation in continuum robots: Closed-form solution, solver and validation
Under Review. The International Journal of Robotics Research (**IJRR**), 2026
Ke Qiu, Fei Wang, Sven Lilge, Yujie Cui, Rong Xiong, Haojian Lu, Yue Wang

An actuator space optimal kinematic path tracking framework for tendon-driven continuum robots
The International Journal of Robotics Research (**IJRR**), 2025
Ke Qiu, Hongye Zhang, Jingyu Zhang, Rong Xiong, Haojian Lu, Yue Wang

An efficient multi-solution solver for the inverse kinematics of 3-section constant-curvature robots
Robotics: Science and Systems (**RSS**), 2023
Ke Qiu, Jingyu Zhang, Danying Sun, Rong Xiong, Haojian Lu, Yue Wang

Learning-based dynamics modeling and robust control for tendon-driven continuum robots
International Conference on Intelligent Robots and Systems (**IROS**), 2026
Ziqing Zou*, Ke Qiu*, Fei Wang, Haojian Lu, Rong Xiong, Yue Wang

Learning the inverse kinematics of magnetic continuum robot for teleoperated navigation
International Conference on Intelligent Robots and Systems (**IROS**), 2024
Pingyu Xiang*, Ke Qiu*, Danying Sun, …, Yue Wang, Rong Xiong, Haojian Lu

Reinforcement learning of serpentine locomotion for a snake robot
International Conference on Real-time Computing and Robotics (**RCAR**), 2021
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AWARDS

IROS Best Paper Award Finalists	*2025*
A4X Robotics Scholarship	*2025*
Outstanding Postgraduate Student, Zhejiang University	*2025, 2023*
Outstanding Graduate of Zhejiang Province, Zhejiang Provincial Government	*2022*
National Scholarship, Ministry of Education, China	*2021*
First-Class Scholarship, Zhejiang University	*2021, 2020, 2019*
First-Class Scholarship, Chu Kochen Honors College	*2021, 2020*
First-Class Scholarship, Department of Mechanical Engineering	*2020, 2019*

ACADEMIC SERVICE

Reviewer for: IEEE Transactions on Robotics (**T-RO**), IEEE Transactions on Soft Robotics (**T-SRO**), IEEE/ASME Transactions on Mechatronics (**TMECH**), IEEE Transactions on Automation Sciences and Engineering (**T-ASE**), Cyborg and Bionic Systems (**CBS**, Science Partner Journal), IEEE International Conference on Robotics and Automation (**ICRA**), IEEE/RSJ International Conference on Intelligent Robots and Systems (**IROS**).

SELF-ASSESSMENT

Strong mathematical foundation with end-to-end research and development experience in robotics. Experienced in non-linear optimisation, state estimation, motion planning, and robot control, with a strong ability to tackle unexpected and novel technical challenges. Adaptable and fast to learn new concepts and technologies, with strong communication and collaboration skills. Responsible, proactive, and highly motivated.

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邱 轲

邮箱: ke.qiu@zju.edu.cn | 电话: 86-18605789012
[Homepage] [Google Scholar]

教育经历

博士(在读) | 浙江大学 *2022 年 9 月 – 2027 年 7 月 (预计)*
控制科学与工程(机器人方向). 导师: 王越, 陆豪健, 熊蓉
曾获浙江大学博士生学业一等奖学金, IROS最佳论文提名, 积加机器人奖学金, 浙江大学优秀研究生等

学士(竺可桢荣誉项目) | 浙江大学 *2018 年 9 月 – 2022 年 7 月*
机械电子工程. 辅修数学. 均绩 3.96/4.0, 均分 89.84/100, 排名前 5%
曾获浙江省优秀毕业生, 国家奖学金, 浙江大学一等奖学金, 竺可桢学院奖学金, 机械工程学院奖学金等

研究经历

基于条件扩散模型(Diffusion)的连续体机器人轨迹规划
- 应对多模态欠约束规划问题, 将其建模为条件概率并训练扩散模型学习运动生成过程, 引入微分运动学梯度引导提升精度, 使用GNN编码变拓扑结构障碍物环境. 提出从任意初始状态运动到目标位置的平滑轨迹生成算法. 该算法具备多模态求解能力, 更高成功率和更短求解时间. 相关成果投稿至机器人顶会ICRA.

可验证全局最优性的机器人时序状态估计
- 解决机器人时序状态估计中的初值依赖和局部线性化问题. 基于Cayley映射将时域位姿变换(或连续体机器人弧长域)过程中的状态估计问题松弛为半正定规划问题, 最小化离散观测误差且满足边界条件约束. 提出精确降维理论和冗余二次约束保持紧性. 使用CVX + MOSEK求解, 实现具有可验证全局最优性的时序状态估计.

连续体机器人全身外力感知: 静力学方程闭式解与高阶状态估计器 [Video]
- 解决多段线驱动连续体机器人的外力估计问题, 提出闭式求解理论, 设计基于高斯过程回归的高阶状态估计算法, 导出随机微分方程先验均值与核函数, 融合光纤布拉格光栅的离散测量获得状态后验分布. 回归采用Gauss–Newton法求解稀疏分块线性系统, 时间复杂度O(n). 实验表明该算法具有更高估计精度和噪声鲁棒性, 计算效率较传统优化(如BFGS)提升约一个数量级. 有效应用于动态力感知与临床场景. 投稿至机器人顶刊IJRR.

连续体机器人驱动空间最优路径跟踪控制 [Paper] [Code] [Media]
- 基于逆运动学多解, 使用动态规划计算驱动空间最短距离路径, 考虑关节约束分配最短时间. 搭建包括离线最优轨迹前馈和在线逆雅可比反馈的控制框架. 设计搭建多段线驱动连续体机械臂硬件, 编写上位机软件(C++)与底层接口(PLC). 实现>100 Hz稳定闭环控制, 实现机器人末端位姿高精度跟踪. 成果发表于顶刊IJRR.

常曲率模型逆运动学的高效多解求解器 [Paper] [Page]
- 针对逆运动学求解中存在的非线性强, 初值依赖, 求解结果单一等问题, 推导解析条件将原方程等价简化为一维问题, 引入有界误差近似从而遍历求解, 保障分辨率完备性. 开发求解算法, 相比传统数值求解器无需提供初值, 改善成功率, 总体计算效率提升 85%, 同时支持多解输出. 成果发表于领域内顶会RSS.

基于黎曼优化的闭运动链机器人运动控制
- 闭链机器人具有关节冗余度高, 形状控制难, 运动生成欠定等问题. 本项目将运动学闭链机器人及其关节约束建模为带边界的黎曼子流形, 构造数值切空间投影和拉回映射实现高维非线性等式约束下的状态更新, 以及处理不等式约束的关节限位. 提出高冗余度闭链机器人的运动生成算法, 实现形状控制和稳定运动生成.

实习经历

实习生 | 浙江人形机器人创新中心有限公司, 宁波 *2024 年 11 月 – 2025 年 1 月*
- 下肢关节参数辨识与控制优化: 实现关节摩擦与阻尼系数的参数辨识算法. 设计实验采集关节数据并进行参数拟合计算. 实现机械传动结构中转子等效惯量计算, 在仿真训练中修正模型参数. 对强化学习策略输出的控制信号进行频域分析(FFT), 根据主导控制频率优化底层驱动器带宽, 提出差异化关节响应频率分配方式. 真机实验证明上述参数修正能改善行走步态和运控稳定性, 同时减小触地噪声.

• 并联机构运动学及安全性分析: 建立踝关节与腰关节所使用并联机构的非线性带约束运动学模型, 推导数值求解算法, 开发C++工具包实现 500 Hz稳定解算. 分析串并联连杆机构静力学, 求解容许工作空间边界及力矩耦合关系, 提供步态强化学习训练中的可行域参数, 有效降低sim2real差距.

实习生 | ABB中国研究院, ABB工程(上海)有限公司, 上海 *2021 年 7 月 – 2021 年 8 月*

• 工业机械臂现场高精度标定算法: 针对工业现场高精度光学标定设备缺失/安装复杂等问题, 提出一套现场标定流程及算法. 基于李群$SE(3)$与李代数$se(3)$建模六自由度工业机械臂正向运动学, 使用标准工件提供的末端位置约束构造非线性最小二乘问题, 使用Levenberg–Marquardt算法迭代求解各关节真实转轴参数, 实现工业现场快速标定, 补偿模型误差提升绝对定位精度. 该算法应用于ABB内部参考的标定软件.

发表论文

在IJRR, RSS等(年发文量约 100 篇, 内地高校<5 篇)领域内顶级期刊和会议上发表论文 5 篇, 总引用量 200+

External force estimation in continuum robots: Closed-form solution, solver and validation
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发明专利

授权发明专利 2 项:

基于高斯过程回归的连续体机器人状态估计方法 CN 122432468 B
一种细长弹性杆的外力估计方法 CN 122413777 B

学术兼职

作为以下期刊及会议审稿人: IEEE Transactions on Robotics (**T-RO**), IEEE Transactions on Soft Robotics (**T-SRO**), IEEE/ASME Transactions on Mechatronics (**TMECH**), IEEE Transactions on Automation Sciences and Engineering (**T-ASE**), Cyborg and Bionic Systems (**CBS**, Science Partner Journal), IEEE International Conference on Robotics and Automation (**ICRA**), IEEE/RSJ International Conference on Intelligent Robots and Systems (**IROS**).

自我评价

具备扎实的数理基础与机器人全栈研发能力. 在非线性优化, 状态估计, 运动规划与控制等方面均有深入研究. 善于学习新知识, 乐于沟通协作. 有责任心, 进取心和工作热情.