刘镕恺

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求职意向-人机交互与机器人方向研究员

个人简介

- **研究背景**: 机器智能和人类智能应当是互补共生的，而不仅仅是通过机器智能取代人类。人机混合智能是解决当下现实需求，使机器具身智能成为人类智能的自然延伸和拓展的一种重要方式。
- **个人优势**: 具有良好的独立科研能力和全面的工程实现能力；具有需求调研分析，科学问题挖掘，人机交互系统和机器人系统软硬件设计开发，算法研究、论文专利撰写等全链条工作能力；具有良好的组织协调能力和团队协作能力。

教育经历

- **中国科学技术大学** 模式识别与智能系统 2020.09 – 2024.06 工学博士学位
  - 研究方向: 人-机器人交互，人机混合智能，模仿学习，康复辅助机器人
  - 学位论文: 面向康复辅助机器人共享控制下的人机交互方法研究
- **中国矿业大学（北京）** 控制理论与控制工程 2017.09 – 2020.06 工学硕士学位
  - 研究方向: 可穿戴人机交互系统，人体运动信息分析，虚拟现实
  - 学位论文: 面向运动康复训练的可穿戴设备步态分析方法研究
- **中国矿业大学（北京）** 电气工程及其自动化 2013.09 – 2017.06 工学学士学位
  - 主修课程: 电力电子技术，自动控制原理，微机原理，C 语言程序设计等

实践经历

- **中国科学院合肥物质科学研究院-智能所智能感知技术研究中心** 全日制研究生 2020.09 – 2024.06
- **中国科学院自动化研究所-复杂系统管理与控制国家重点实验室** 科研助理 2017.06 – 2020.08
- **北京中科鸿泰医疗机器人有限责任公司** 机器人嵌入式系统实习生 2019.05 – 2019.08

论文发表

- **R. Liu**, Q. Song, T. Ma, and H. Pan, "Toward Remapping Residual Movement of Shoulder: A Soft Body-Machine Interface," *IEEE Transaction on Neural System and Rehabilitation (T-NSRE).*, Under Review. (IF:4.9)
- **R. Liu**, T. Ma, and N. Yao et al., "Adaptive Symmetry Reference Trajectory Generation in Shared Autonomy for Active Knee Orthosis," *IEEE Robotics and Automation Letters (RA-L) with IROS 2023*, vol. 8, no. 6, pp. 3118–3125, Jun. 2023. (IF:5.2)
- L. Tong, **R. Liu**, and L. Peng, "LSTM-Based Lower Limbs Motion Reconstruction Using Low-Dimensional Input of Inertial Motion Capture System," *IEEE Sensors Journal*, vol. 20, no. 7, pp. 3667–3677, Apr. 2020.(IF:4.3, 导师一作)
- X. Zhao, **R. Liu**, and T. Ma et al, "Real-time Gait Phase Estimation Based on Multi-source Flexible Sensors Fusion," in 2023 3rd International Conference on Robotics and Control Engineering(RobCE2023), Nanjing, China: ACM, May. 2023, in production.
- **R. Liu**, L. Peng, and L. Tong et al, "A Novel Method for Parkinson' s Disease Classification and Dyskinesia Quantification Using Wearable Inertial Sensors," in 2019 IEEE 9th Annual International Conference on CYBER Technology in Automation, Control, and Intelligent Systems (CYBER), Suzhou, China: IEEE, Jul. 2019, pp. 1022–1026.

- **R. Liu**, L. Peng, and L. Tong et al., "The Design of Wearable Wireless Inertial Measurement Unit for Body motion Capture System," in 2018 IEEE International Conference on Intelligence and Safety for Robotics (ISR), Shenyang: IEEE, Aug. 2018, pp. 557–562.
- Y. Wang, Q. Song, T. Ma, Y. Chen, H. Li, and **R. Liu**, "Transformation classification of human squat/sit-to-stand based on multichannel information fusion," *International Journal of Advanced Robotic Systems*, vol. 19, no. 4, Jul. 2022.(IF:2.3)

专利

- 彭亮，侯增广，刘镕恺《帕金森病人运动障碍量化及识别的可穿戴设备》
- 彭亮，侯增广，刘镕恺《基于支持向量机的帕金森病人运动障碍量化及识别方法》
- 宋全军，刘镕恺，马婷婷《一种基于共享自治系统的步态对称性康复机器人轨迹规划算法》（在审）
- 宋全军，刘镕恺，马婷婷《一种非侵入式柔性人机交互接口》（在审）

科研项目

- **基于大数据的自然交互意图理解和智能输入** 国家重点研发计划云计算和大数据专项 参与
  - 针对 BCI 目前难以实现动态环境下连续操控的问题，基于电容式柔性应变传感器网络和 IMU，主导设计了一种非侵入式体-机交互界面 (SoftBoMI) 捕捉人体肩部运动以产生连续操控指令控制辅助设备;
  - 设计了交互接口数据在线解析、校准、数据可视化界面，并基于 Unity3D 搭建了轮椅操控虚拟仿真环境;
  - 针对用户肩部动作存在不确定性的问题，以共享自治为主要思想，设计了用户意图推理介入数据解码框架，通过引入先验知识设计指令空间流形，在保证交互界面的动态性能的前提下提高了操控准确性。
- **脑卒中康复机器人** 国家重点研发计划智能机器人专项 参与
  - 主导设计并带领团队搭建了一套膝关节外骨骼机器人系统，将实时采集的患者健侧步态运动轨迹映射到患侧驱动器执行诱导步态对称性恢复;
  - 通过非线性频率振荡器与下肢运动进行耦合形式化表示步态周期时间特征，基于机器人模仿学习算法设计了一个编码器-解码器结构的步态轨迹时间序列在线学习与复现算法框架;
  - 通过采集标准步态数据构建了一个概率形式的机器人步态技能库用于提供机器策略;
  - 针对用户下肢健侧输入存在不确定性的问题，基于一个共享自治框架实现了用户健侧输入的在线验证消歧和微调以提高机器人系统安全性。
- **面向机器人交互的柔性应变传感器研制与应用** 安徽省重点研发-长三角 参与
  - 为柔性应变传感器在人-机器人交互方面提供应用场景支撑和验证。
- **脑损伤康复机器人系统关键技术及康复功能评价方法** 国家自然科学基金 参与
  - 负责人体无线惯性运动捕捉系统的设计与研发工作;
  - 完成基于 MEMS 惯性传感器的人体运动捕捉系统的软硬件设计和基于 Unity3D 的虚拟人实时映射程序开发;
  - 基于 LSTM 神经网络提出了一种基于稀疏惯性传感器节点的人体下肢运动重建方法。
- **可穿戴设备在帕金森慢病管理中的应用** 北京市自然科学基金重点项目 参与
  - 设计了一套可实现多路 IMU 信号、EMG 信号、视频信号的可穿戴同步数据采集系统，用于建立多模态帕金森运动障碍数据集;
  - 基于 BLE 和 NB-IoT 实现了采集数据本地或云端的无线上传;
  - 采用所开发系统数据采集系统在北京协和医院神经科完成 70 例典型帕金森患者的运动信息采集，构建了帕金森症状量化评估数据集（包含上肢运动能力，步态运动信息，视频信息以及声音等）;
  - 对实验采集所得数据进行标准化处理和数据挖掘，结合领域专家知识进行特征工程，基于 RBF-SVM 实现了帕金森患者的步态障碍和运动能力的量化评估与异常步态检测。
- **基于 sEMG 和 FES 的上肢康复机器人自适应主动控制方法研究** 国家自然科学基金青年基金 参与
  - 负责五自由度外骨骼上肢康复机器人的通讯与运动控制嵌入式系统的研发和调试;

  - 基于 Unity3D 为 6-DOF 和 2-DOF 上肢康复机器人开发了虚拟现实康复训练系统。

- **智能轮椅助行车技术研发与产业化** 中国科学技术大学“双创基金” 主持
  - 负责项目总体构思和申报工作；
  - 围绕实验室基础和现有研究成果布局未来可能的产业化方向，开展初步市场需求调研。

在研课题

- **步态对称性康复机器人人在环中辅助策略优化**
  - 基于已搭建的步态对称性康复机器人平台，以步态时间对称性和空间对称性为优化目标，采用贝叶斯优化等黑盒优化方法对关节力矩辅助策略进行优化以提高偏瘫患者步态表现；
  - 与已开发的对称步态轨迹生成算法结合，设计机器人关节力-位混合控制策略。
- **人机共享控制下的辅助机械臂操控**
  - 基于所开发的非侵入式体-机交互接口，采用 Pybullet 机器人物理仿真环境设计辅助机械臂遥操作任务空间；
  - 通过采集熟练操作者操控序列并基于 GAIL 等生成式模仿学习算法构建机器智能策略，设计人机混合共享自治模型，将先验知识融入到交互接口的指令生成中，降低多自由度辅助机器人的操控难度和学习成本。

技能

- **编程语言**：Python、C/C++、C#、Matlab、LaTex
- **软件开发**：QT、Unity3D、Pybind11、RabbitMQ、ROS、PyBullet、WinForm、Simulink
- **数据分析与可视化**：熟练使用 Numpy, Scipy, Pandas 等数据分析库以及 Matplotlib、Seaborn、Pyqtgraph 等静态与动态科研绘图库。
- **算法研究**：
  - 熟练掌握常用机器学习算法以及 SK-Learn、Pytorch、Tsfresh 等算法开发框架；
  - 熟悉贝叶斯学派下的 HMM、KF、EKF、MDP 等随机系统时间序列分析与建模等理论知识；
  - 熟悉 DMP、pDMP、GP、GMM、BC、非线性振荡器等机器人模仿学习算法；
  - 了解 LQR、MPC 以及强化学习等优化控制算法理论；
  - 了解 AE、VAE、GAIL 等生成式模型理论。
- **硬件开发**：
  - 掌握机器人电气驱动系统的设计与调试；
  - 熟悉机器人系统的整体架构，熟练掌握基于 Linux 和 RTOS 平台的嵌入式系统的开发；
  - 熟悉 BLE、2.4G 等常用无线通讯协议的软硬件开发。

兴趣爱好及所获荣誉

- 吉他、摄影、阅读、羽毛球
- **2022**：中国科学技术大学一等学业奖学金
- **2021**：中国科学技术大学一等学业奖学金
- **2021**：中科院合肥物质研究院智能所优秀党员
- **2020**：中国矿业大学（北京）优秀毕业生
- **2018**：中国矿业大学（北京）二等学业奖学金
- **2016**：北京市大学生电子设计大赛省级二等奖
- **2016**：“中国乐势力”全国校园乐队大赛北京赛区冠军
- **2015**：优秀学生干部（院学生会副主席）
- **2014**：优秀学生干部（院学生会文艺部部长）

Rongkai Liu

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Aim: HRI and Robotic Researcher http://EricRongkai.github.io (Homepage)

PERSONAL INTRODUCTION

- **Research Background**: Artificial intelligence and human intelligence should be complementary and coexist, rather than simply replacing humans with robots.
- **Personal Advantages**: Good independent scientific research ability and comprehensive engineering realization ability; ability to work on the whole chain of tasks from demand research and analysis, scientific problem mining, innovative human-machine system and robot system prototype hardware and algorithm design and development; good organization and coordination ability and teamwork ability.

EDUCATION

- **University of Science and Technology of China** 2020.09 – 2024.06 Ph.D.
  - **Major**: Pattern Recognition and Intelligent Systems
  - **Research Interest**: HRI, Human robot collaboration, Rehabilitation robotics
- **China University of Mining and Technology-Beijing** 2017.09 – 2020.06 M.S.
  - **Major**: Control Theory and Control Engineering
- **China University of Mining and Technology-Beijing** 2013.09 – 2017.06 B.S.
  - **Major**: Electrical engineering and automation

WORK EXPERIENCES

- **Hefei Institute of Physical Sciences, CAS** *Full-time graduate student* 2020.09 – 2024.06
- **Institute of Automation, CAS** *Research Assistant* 2017.06 – 2020.08
- **Beijing Zhongke Hongtai Medical Robotics Co.** *Internship* 2019.05 – 2019.08

PUBLICATIONS

- **R. Liu**, Q. Song, T. Ma, and H. Pan, "Toward Remapping Residual Movement of Shoulder: A Soft Body-Machine Interface," *IEEE Transaction on Neural System and Rehabilitation (T-NSRE).*, Under Review. (IF:4.9)
- **R. Liu**, T. Ma, and N. Yao et al., "Adaptive Symmetry Reference Trajectory Generation in Shared Autonomy for Active Knee Orthosis," *IEEE Robotics and Automation Letters (RA-L) with IROS 2023*, vol. 8, no. 6, pp. 3118–3125, Jun. 2023. (IF:5.2)
- L. Tong, **R. Liu**, and L. Peng, "LSTM-Based Lower Limbs Motion Reconstruction Using Low-Dimensional Input of Inertial Motion Capture System," *IEEE Sensors Journal*, vol. 20, no. 7, pp. 3667–3677, Apr. 2020.(IF:4.3)
- X. Zhao, **R. Liu**, and T. Ma et al, "Real-time Gait Phase Estimation Based on Multi-source Flexible Sensors Fusion," in 2023 3rd International Conference on Robotics and Control Engineering(RobCE2023), Nanjing, China: ACM, May. 2023, in production.
- **R. Liu**, L. Peng, and L. Tong et al, "A Novel Method for Parkinson' s Disease Classification and Dyskinesia Quantification Using Wearable Inertial Sensors," in 2019 IEEE 9th Annual International Conference on CYBER Technology in Automation, Control, and Intelligent Systems (CYBER), Suzhou, China: IEEE, Jul. 2019, pp. 1022–1026.

- **R. Liu**, L. Peng, and L. Tong et al., "The Design of Wearable Wireless Inertial Measurement Unit for Body motion Capture System," in 2018 IEEE International Conference on Intelligence and Safety for Robotics (ISR), Shenyang: IEEE, Aug. 2018, pp. 557–562.

PATENTS

- L. Peng, Z. Hou, **R. Liu** "Wearable devices for quantifying and recognizing dyskinesia in Parkinson's patients"
- L. Peng, Z. Hou, **R. Liu** "Quantification and identification of dyskinesia in Parkinson's patients based on support vector machine"
- Q. Song, **R. Liu**, T. Ma "A non-invasive flexible body-machine interaction interface" (Under Review)

RESEARCH PROJECTS

- **Big Data-based Intent Understanding and Intelligent Input for Natural Interaction**
  National Key Research and Development Program
  - Devised a non-invasive body-machine interaction interface (SoftBoMI) utilizing soft strain sensors and an inertial measurement unit. This interface captures shoulder movements to generate control commands for assisting devices.
  - Designed the online parsing, calibration and data visualization software, and built a virtual simulation environment for wheelchair manipulation based on Unity3D;
  - Designed a data decoding framework for user intent inference intervention with shared autonomy, which improves the manipulation accuracy and the dynamic performance of the interface.
- **Stroke Rehabilitation Robot**
  National Key Research and Development Program for Intelligent Robots
  - Built a knee exoskeleton robotic system that maps real-time captured gait motion trajectories from the patient's healthy side to the affected side's actuator, aiming to perform induced gait symmetry restoration;
  - Designed an encoder-decoder algorithmic framework for online learning and reproduction of gait trajectory time series based on robot imitation learning algorithms.
  - Constructed a probabilistic form of robot gait skill library by collecting standard gait data, aimed at providing machine strategies.
  - Designed an online validation, disambiguation, and fine-tuning process for user inputs, realized through a shared autonomy framework, aimed at enhancing the safety of the robotic system.
- **Key technology of brain injury rehabilitation robot system and function evaluation**
  National Natural Science Foundation of China
  - Responsible for the design and development of a wireless inertial motion capture system for the human body;
  - Completed the software and hardware design of human motion capture system based on MEMS inertial sensors and the development of virtual human real-time mapping program based on Unity3D;
  - Proposed a human lower limb motion reconstruction method based on sparse inertial sensor nodes based on LSTM neural network.
- **Wearable devices in Parkinson's chronic disease management**
  Beijing Natural Science Foundation Key Program
  - Designed a wearable synchronous data acquisition system that record multiple IMU, EMG and video signals;
  - Realized wireless uploading of collected data locally or in the cloud based on BLE and NB-IoT;
  - Collected movement data from 70 typical Parkinson's patients in the Department of Neurology of Peking Union Medical College Hospital;
  - Designed a quantitative assessment method of gait impairment in Parkinson's patients based on RBF-SVM.
- **Research on adaptive control for upper limb rehabilitation robot based on sEMG and FES**
  National Natural Science Foundation of China Youth Fund

  - Responsible for the development and debugging of the communication and motion control embedded system for a five-degree-of-freedom exoskeleton upper limb rehabilitation robot;
  - Developed virtual reality rehabilitation training systems based on Unity3D for 6-DOF and 2-DOF upper limb rehabilitation robots.

- **Research, development and industrialization of intelligent wheelchair**
  University of Science and Technology of China "Innovation and Entrepreneurship Fund"
  - Responsible for overall project planning and reporting;
  - Carried out preliminary market demand research.

RESEARCHES IN PROGESS

- **Human-in-the-loop assistive strategy optimization for gait symmetry rehabilitation**
  - Using Bayesian optimization to optimize the joint moment assisting strategy to improve the gait symmetry performance of hemiplegic patients;
  - Design of hybrid force-position control strategies for robot joints in conjunction with a developed symmetric gait trajectory generation algorithm.
- **Assisted robotic arm teleoperation under shared control**
  - Design of an assisted robotic arm teleoperation task space based on the Pybullet robot physics simulation environment;
  - By collecting manipulation data from skilled users, we are designing a hybrid shared autonomy model to reduce the manipulation difficulty and learning cost of multi-degree-of-freedom assistive robots.

SKILLS

- **Programming Language**: Python, C/C++, C#, Matlab, LaTex
- **Software Development**: QT, Unity3D, Pybind11, RabbitMQ, ROS, PyBullet, WinForm, Simulink
- **Data Analysis and Visualization**: Proficiency with data analysis libraries such as Numpy, Scipy, Pandas, and static and dynamic scientific research plotting libraries such as Matplotlib, Seaborn, and Pyqtgraph.
- **Agorithm Research**:
  - Proficiency in machine learning algorithm development frameworks such as SK-Learn, Pytorch, Tsfresh, etc.;
  - Familiar with the theory of time series analysis and modeling of stochastic systems under the Bayesian school such as HMM, KF, EKF, MDP, etc.;
  - Familiar with robot imitation learning algorithms such as DMP, pDMP, GP, GMM, BC, nonlinear oscillator, etc.;
  - Understanding of the theory of optimal control algorithms such as LQR, MPC, and reinforcement learning;
  - Understanding of generative modeling theories such as AE, VAE, GAIL, etc.
- **Hardware Development**:
  - Mastering the design and commissioning of robot electrical drive systems;
  - Familiar with the overall architecture of robotic systems, proficient in the development of embedded systems based on Linux and RTOS platforms;
  - Familiar with software and hardware development of wireless communication protocols such as BLE, 2.4G.

HONORS

- **2021**: First Class Academic Scholarship of USTC
- **2020**: Outstanding Graduates of CUMTB
- **2016**: Second Prize of Beijing University Students Electronic Design Competition
- **2016**: Champion of "China Music Power" National School Band Competition Beijing Region
- **2015**: Outstanding Student Leader (Vice-President of the Faculty Student Union)