JIRUI FU

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RESEARCH AREA

- Design and control of wearable robotic systems, including exoskeletons and exosuits, tailored for user-specific needs.
- Development and rigorous validation of exoskeleton and exosuit technologies for both assistance in daily activities and rehabilitation purposes.
- Integration of cable-driven mechanisms, ergonomic interfaces, and human-in-the-loop control systems to enhance the functionality and user experience of wearable exoskeletons and exosuits.
- Advanced experimental tools and methodologies for the real-time monitoring and analysis of human physiology, movement biomechanics, behaviors, and physical performance indicators.
- Exploration and application of deep reinforcement learning techniques in the fields of biomedical engineering and biomechanics, aiming to innovate and improve research outcomes.

EDUCATION

Doctor of Philosophy in Mechanical Engineering — January 2020 - August 2024
University of Central Florida, Orlando, FL
Dissertation: Design and Validation of a Myoelectric Bilateral Cable-Driven Upper Body Exosuit and a Deep Reinforcement Learning-based Motor Controller for an Upper Extremity Simulator
Advisor: Joon-Hyuk Park, Ph.D.

Master of Science in Mechanical Engineering — January 2018 - December 2019
University of Southern California, Los Angeles, CA
GPA: 3.69

Bachelor of Science with honor in Mechanical Engineering — August 2013 - December 2017
Graduated Megna Cum Laude
Florida Institute of Technology, Melbourne, FL
GPA: 3.74

RESEARCH EXPERIENCE

Graduate Research Assistant (Advisor: Dr.Joon-Hyuk Park)
Wearable Engineering and Assistive Robotics Laboratory — January 2020 - Present
University of Central Florida, Orlando, FL

1. **Myoelectric Cable Driven Upper Body Exosuit for Bilateral Human Power Augmentation** (Major Project)
    - *Engineered a Cable-Driven Soft Exosuit:* Designed and built an upper limb exosuit to reduce the risk of work-related musculoskeletal disorders during load-carrying and eye-level tasks.
    - *Developed Myoelectric Control Systems:* Programmed a proportional myoelectric control system with an admittance controller using LabVIEW and NI FPGA, integrating surface EMG and IMU sensors for precise control of the upper limb exosuit in load-carrying and eye-level applications.
    - *Conducted Human Subject Research:* Developed an IRB protocol for human subject experiments to validate the exosuit's effectiveness in reducing muscle fatigue, and conducted research on human biofeedback while using the exosuit.

    Relevant Skills: CAD modelling at Solidworks; FDM and SLA 3D Print; LabVIEW; NI MyRio; NI FPGA; Inverse and Forward Dynamics; Inverse and Forward Kinematics; EMG Sensor; IMU Sensor; Control Engineering; EMG Data Processing; Manage and Conduct Human Subject Experiment

2. **Deep Reinforcement Learning-based Motor Controller of Upper Limb Neuromusculoskeletal Simulator** (Major Project)

   - *Engineered Neuromusculoskeletal Simulation:* Developed an upper limb neuromusculoskeletal simulation using the MyoSuite model within the Mujoco physics engine to replicate elbow joint movements with and without exoskeleton assistance.
   - *Innovated Deep Reinforcement Learning Auto-Tuner:* Constructed a novel deep reinforcement learning-based auto-tuner for the human central nervous system's internal model, eliminating the need for experimental data or prior knowledge.
   - *Proven Efficacy of Auto-Tuner:* Demonstrated the efficiency of the deep reinforcement learning-based auto-tuner in accurately tuning the internal model of the central nervous system.
   - *Benchmarking and Performance Improvement:* Benchmarked the auto-tuner against a deep reinforcement learning agent trained to output muscle activation, showcasing enhanced accuracy and reduced response time with the auto-tuner.

   Relevant Skills: Deep Reinforcement Learning; Python Programming; Numpy; Pytorch; Mujoco; MyoSuite;

3. **Design and Construction of Cable-driven Ankle Perturbation System to Study Biomechanics of Balance Control in Healthy Adults**

   - *Engineered Cable-Driven Ankle Perturbation System:* Designed and built a system that uses cable force to control ankle acceleration and deceleration in the sagittal plane, inducing slip or trip perturbations during walking.
   - *Validated System Efficacy:* Conducted validation studies demonstrating the system's ability to deliver random, unanticipated slip and trip perturbations of varying intensities at specific points in the gait cycle.

   Relevant Skills: Biomechanical Data Collection; Control Engineering; Manage and Conduct Human Subject Experiment

4. **Evaluation of a Variable Resistance Suit for Muscle Hypertrophy**

   - *Human Subject Experimentation:* Assisted in conducting human subject experiments to validate the efficiency of the proposed system.
   - *Research Documentation and Data Visualization:* Contributed to writing research literature and creating relevant plots for data analysis and publication.

   Relevant Skills: Biomechanical Data Collection; Manage and Conduct Human Subject Experiment; Scientific Writing

Graduate Research Assistant (Advisor: Dr.Yan Jin)
IMPACT Laboratory June 2018 - December 2019
University of Southern California, Los Angeles, CA

1. **Multi-agent Robotic System for Cooperative Tasks**

   - *Developed Computational Simulation Platform:* Created a sophisticated multi-agent robot simulation within the Pygame framework for training deep reinforcement learning applications.
   - *Implemented Deep Reinforcement Learning Algorithms:* Applied advanced deep reinforcement learning algorithms for precise multi-agent robot control, with a focus on collision avoidance.
   - *Engineered Multi-Agent Robotic System:* Designed and assembled a multi-agent robotic system using Arduino and Raspberry Pi for efficient execution of complex control algorithms.
   - *Created Robust Communication Framework:* Developed an MQTT-based communication framework for seamless data exchange and coordination among agents in the multi-agent robotic system.
   - *Developed Vision-Based Monitoring System:* Implemented a vision-based monitoring and navigation system using OpenCV and AprilTag System for enhanced operational efficiency and real-time image processing.

   Relevant Skills: Python Programming; Arduino; Raspberry Pi; MQTT; Solidworks; OpenCV; FDM 3D Print; AprilTag; Deep Reinforcement Learning

SELECTED PUBLICATIONS

Peer-Reviewed Journals

1. **Fu, Jirui**, Renoa Choudhury, Saba M. Hosseini, Rylan Simpson, and Joon-Hyuk Park. 2022. "Myoelectric Control Systems for Upper Limb Wearable Robotic Exoskeletons and Exosuits—A Systematic Review" Sensors 22, no. 21: 8134
2. Kim, Jong-Hwan, Segi Kwon, **Jirui Fu**, and Joon-Hyuk Park. 2022. "Hair Follicle Classification and Hair Loss Severity Estimation Using Mask R-CNN" Journal of Imaging 8, no. 10: 283.
3. Mohammad Hosseini, Saba, Amir Farhad Ehyaei, Joon-Hyuk Park, **Jirui Fu**, and Amirhossein Safari. "A constrained model predictive controller for two cooperative tripod mobile robots." Transactions of the Institute of Measurement and Control 45, no. 10 (2023): 1999-2011.
4. Kadhim Ibrahim F., Chitra Banarjee, **Jirui Fu**, Renoa Choudhury, L. Colby Mangum, David H. Fukuda, Jeffrey R. Stout, Joel T. Cramer, and Joon-Hyuk Park. "Resistance Training Using Variable Resistance Suit (Vars) Increased Isometric and Isokinetic Muscle Strength." IEEE Transactions on Neural Systems and Rehabilitation Engineering (2024).

Peer-Reviewed Conferences

1. **J. Fu**, R. Choudhury and J. -H. Park," Deep Reinforcement Learning Based Upper Limb Neuromusculoskeletal Simulator for Modelling Human Motor Control," 2023 IEEE International Conference on Systems, Man, and Cybernetics (SMC), Honolulu, Oahu, HI, USA, 2023, pp. 2789-2795
2. **J. Fu**, S. M. Hosseini, R. Simpson, A. Brooks, R. Huff, and J.-H. Park, "A Bilateral Six Degree of Freedom Cable-driven Upper Body Exosuit," in 2022 IEEE International Conference on Mechatronics and Automation (ICMA), 2022, pp. 617–623. **(Best Student Paper Award)**
3. B. Lu, **J. Fu**, S. M. Hosseini, and J.-H. Park, "Modeling and Characterization of 3D Printed Flexible Mesh Structure for Wearable Interface," in 2022 9th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob), 2022, pp. 01–08.

Book Chapter

1. **J. Fu**, Z. Al-Mashhadani, K. Currier, A.-M. Al-Ani, and J.-H. Park, "Challenges and Trends of Machine Learning in the Myoelectric Control System for Upper Limb Exoskeletons and Exosuits," 2023.

Under Revision Publications

1. Davasundaram Surendar, **Jirui Fu**, Mark Aldritz Dela Virgen, Andrea Raymond, Drue Shaprio, and Joon-Hyuk Park. "Reconfigurable Multimodel Wearable Sensor Network to Facilitate Customizable, Modular and Scalable Health and Ambience Monitoring." International Journal of Distributed Sensor Networks (2024).

Under Review Publications

1. K. Currier, **J. Fu**, N. Bayat, Y. Fu, J.-H. Kim, and J.-H. Park, "Myoelectric Hand Gesture Recognition using Variational Autoencoder and Sensor Fusion," Nature Scientific Report, 2024

Under Prepare Publications

1. **Fu, Jirui**, Ibrahim F. Kadhim, Keith Currier, Bhavani Sivakumaar, and Joon-Hyuk Park. "Design and Validation of a Bilateral Cable-Driven Upper Body Exosuit Controlled by Human Movement Intention for Power Augmentation." IEEE Robotics & Automation Letter(2024).

CONFERENCE PRESENTATION

1. 2022 IEEE International Conference on Mechatronics and Automation (ICMA), Guilin, Guangxi China
2. 2023 IEEE Conference on Systems, Man, and Cybernetics (SMC), Honolulu, Oahu, HI United States

HONOR AND AWARD

1. **Best Student Paper Award** at the 2022 IEEE International Conference on Mechatronics and Automation (ICMA), Guilin, Guangxi, China, August 7-10, 2022 for the paper: "A Bilateral Six Degree of Freedom Cable-driven Upper Body Exosuit".

FELLOWSHIP AND GRANT

1. **Graduate Dean's Dissertation Completion Fellowship** offered by the College of Engineering and Computer Science of the University of Central Florida (January 2024)
2. **Student Travel Grant** offered by the Institute of Electrical and Electronics Engineers (IEEE) (November 2023)
3. **Graduate Student Travel Fellowship** offered by the College of Graduate Study of the University of Central Florida (June 2023)
4. **Graduate Student Open Access Publication Fellowship** offered by the College of Graduate Study of the University of Central Florida (May 2023)
5. **Undergraduate Student Tuition Scholarship** offered by the Florida Institute of Technology (August 2015 – December 2017)

TEACHING EXPERIENCE

Graduate Teaching Assistant
Department of Mechanical Engienering January 2020 - December 2023
University of Central Florida, Orlando, FL

1. EML-3303C Engineering Measurement Laboratory, Instructor: Dr. Hansen Mansy
   - Every semester from Spring 2022 – Fall 2023
   - Lead laboratory and help the undergraduate students finish the required lab.
2. EML-4313 Intermediate System Dynamics and Control, Instructor: Dr. Tuhin Das
   - Every fall semester from 2020 - 2021.
   - Help the instructor prepare the lecture materials and proctor the mid-term and final exam.
   - Host office hours to answer student's questions.
3. ENG-3321 Engineering Analysis – Dynamics, Instructor: Dr. Marino Nader
   - Spring 2021
   - Host office hours to answer students' questions, host recitation sessions for students, design questions in practice exam and some homework assignments.
4. EAS-5407 Mechatronics System, Instructor: Dr. Joon-Hyuk Park
   - Summer 2020
   - Involve in the design of lectures, homework assignments, and exam questions of this course.
5. EML-4306 Energy System Laboratory, Instructor: Sagnik Mazumdar
   - Spring 2020
   - Lead laboratory and help the undergraduate students finish the required lab.

Graduate Teaching Assistant
Department of Mechanical Engienering August 2019 - December 2019
University of Southern California, Los Angeles, CA

1. AME-305 Mechanical Design, Instructor: Dr. Oussama Safadi
    - Fall 2019
    - Host office hours to answer students' questions and grade students' homework assignments.

STUDENT MANTEE

Department of Mechanical Engineering, University of Central Florida, Orlando, FL

1. Keith A. Curieer
    - Committee Member and Co-advisor of Undergraduate Honor Thesis.
    - Thesis: Variational Autoencoder and Sensor Fusion for Robust Myoelectric Controls
    - Duration: Summer 2022 – Fall 2023

PROFESSION SOCIETY MEMBERSHIP

1. Student Member of the Institute of Electrical and Electronics Engineers (IEEE)
    - Member of the Engineering in Medicine and Biology Society
    - Member of the Robotics and Automation Society
    - Member of the System, Man, and Cybernetics Society
2. Student Member of the American Society of Mechanical Engineers (ASME)

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