Qiang Zhang, Ph.D. Candidate

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EDUCATION

Post-Doc research fellow in the Closed-Loop Engineering for Advanced Rehabilitation (CLEAR) 11/2021 - Present
University of North Carolina at Chapel Hill and North Carolina State University, NC, USA

Advisor: Dr. Michael Lewek and Dr. He (Helen) Huang

Ph.D. in Biomedical Engineering 08/2019 - 11/2021
University of North Carolina at Chapel Hill and North Carolina State University, NC, USA
Advisor: Dr. Nitin Sharma and Dr. Kang Kim
Dissertation Title: "Ultrasound Imaging and Surface Electromyography-based Voluntary Effort Prediction and Control Strategies for Ankle Assistance"

M.S. in Mechanical Engineering 08/2017 - 08/2019
University of Pittsburgh, Pittsburgh, PA, USA
Advisor: Dr. Nitin Sharma and Dr. Kang Kim

M.S in Mechatronics Engineering 09/2014 - 07/2017
Wuhan University, Wuhan, Hubei, China
Advisor: Dr. Xiaohui Xiao and Dr. Zhao Guo
Thesis Title: "Design and Control of a Cable-Driven Upper Limb Rehabilitation Exoskeleton Robot Using Series Elastic Actuator"

B.S. in Mechanical Engineering 09/2010 - 06/2014
Wuhan University, Wuhan, Hubei, China

RESEARCH INTERESTS

- Lyapunov-based nonlinear control, adaptive impedance control
- Human-in-the-loop control design for wearable exoskeleton
- Neuromuscular modeling and function electrical stimulation (FES) control
- Surface electromyography (sEMG) and ultrasound imaging signal processing
- Human lower limb joint motion intention detection
- Human walking movement kinematics and kinetics analysis
- Cable-driven ankle exoskeleton design and assist-as-needed control
- Serial elastic actuator design and control
- Linear/nonlinear observer design
- Sensor fusion with multiple sampling rates
- Human-robot interaction

RESEARCH EXPERIENCE

Research assistant (08/2019 - Present)
UNC/NCSU Joint Department of Biomedical Engineering - *North Carolina State University, Raleigh, NC*
Neuromuscular Control and Robotics Lab (Advisors: Dr. Nitin Sharma and Dr. Kang Kim)
Project: Ultrasound-based Intent Modeling and Control Framework for Neurorehabilitation (*Supported by NSF Career Award # 1750748*)

- Investigated deep convolutional neural network – based deep feature extraction from skeletal muscle's ultrasound imaging to predict net joint moment for dynamic tasks, including sitting-to-standing and walking at different speeds.
- Proposed to use sEMG and US imaging-derived feature fusion to predict ankle dorsiflexion motion during walking swing phase by applying multiple machine learning approaches, including support vector machine regression, feedforward neural network, multiple linear regression, and Gaussian process regression.
- Investigated to combine sEMG and US imaging-derived features together with ankle joint kinematics to predict ankle joint kinetics (net joint torque) during the walking stance phase on a treadmill with multiple speeds based on a newly proposed sEMG-US imaging-driven Hill-type neuromuscular model and multiple machine learning models.
- Designed and manufactured a cable-driven bidirectionally actuated ankle joint exoskeleton and proposed an adaptive impedance controller-based assist-as-needed control framework for ankle plantarflexion assistance during walking stance phase with the consideration of ankle joint volitional net moment prediction using sEMG-US imaging-driven Hill-type neuromuscular model.
- Proposed a virtual constrain (taking the thigh and shank orientation as the phase variable)-based ankle joint trajectory tracking control during the walking swing phase elicited by neuromuscular electrical stimulation (NMES) with the consideration of tibialis anterior muscles activation level measured from US imaging.
- Proposed a sampled-data observer + dynamic surface control + delay compensator frame for NMES-elicited ankle dorsiflexion trajectory tracking control problem, while considering the low rate-sampled US imaging measurement of muscle activation and fatigue as bio-feedback.
- Collaborated on the study of model predictive control for human elbow joint trajectory tracking by NMES-elicited stimulation of antagonistic muscles including biceps brachii and triceps brachii muscles.

Research assistant (08/2017 - 08/2019)
Department of Mechanical Engineering and Materials Science - *University of Pittsburgh, Pittsburgh, PA*
Neuromuscular Control and Robotics Lab (Advisors: Dr. Nitin Sharma and Dr. Kang Kim)
Project: Ultrasound-based Intent Modeling and Control Framework for Neurorehabilitation (*Supported by NSF Career Award # 1750748*)

- Developed offline imaging processing algorithms to extract structural features, including pennation angle and fascicle length, and functional features, including echogenicity, tissue displacement, and tissue strain from skeletal muscle ultrasound imaging.
- Proposed to use surface electromyography (sEMG) and ultrasound (US) imaging-derived feature fusion as inputs of a modified Hill-type neuromuscular model for predicting human ankle joint net dorsiflexion and plantarflexion moment under isometric conditions.
- Developed a continuous observer for a class of nonlinear neuromusculoskeletal systems with multi-rate and delayed output measurements from inertial measurement unit (IMU) and US imaging.
- Collaborated on iterative learning control development of a lower limb hybrid neuroprosthesis (NMES + powered motors) to track virtual constraint-based desired trajectories for both knee and hip joints during a sit-to-stand task.

Research assistant (11/2013 – 07/2017)
School of Power and Mechanical Engineering - *Wuhan University, Wuhan, Hubei, China*
(Advisors: Dr. Xiaohui Xiao and Dr. Zhao Guo)
Project: Research on Bionic Mechanism and Optimization Design Methodology of Skeletal Muscle-like Variable Stiffness Actuator (*Supported by NSFC, No. 51605339*)

- Developed the hardware and control platform of a portable upper limb exoskeleton prototype with 4 active DOFs and 2 passive DOFs, active DOFs were actuated by series elastic actuators (SEAs) and Bowden cables.
- Based on feedback linearization control strategy, achieved SEA motion tracking control and force control, upper limb exoskeleton impedance control.

Project: Research on 4-DOFs Underactuated Bipedal Walking Robot

- Developed the hardware of an underactuated bipedal walking robot with 4 active DOFs, and established the prototype's equivalent multiple rigid link model to plan periodic stable off-line gait based on Poincáre return mapping method.
- Developed the National Instrument single-board RIO-based control system of the bipedal walking robot, and programmed LabVIEW code to actuate the robot walking locomotion at a hung state in an open-loop manner.
- Collaborated on a human-inspired adaptive feedforward control strategy to stabilize the robot's underactuated bipedal walking locomotion on a compliant ground.

Project: Study on Coupling Dynamics and Gait Planning of 10-DOFs Bipedal Robot Walking on Compliant Ground (*Supported by NSFC, No. 51175383*)

- Developed a 3-D CAD model of a fully actuated bipedal walking robot with 10 DOFs and performed the key components' stress analysis based on FEA software.
- Based on the zero moment point criterion, planned the walking locomotion gait of the 10 DOFs bipedal robot walking on stiff ground and performed the virtual prototype dynamic simulation in ADAMS.
- With the same walking gait, investigated the effect on kinematics and kinetics during a single support phase by changing the spring stiffness added on the ankle and knee flexible joints through dynamic simulation in ADAMS.
- Developed the ground compliance model based on distributed spring-damper system and performed compliant ground-rigid robot coupling simulations to investigate the effects of ground compliance on bipedal robot dynamic properties.
- Collaborated on a real-time 3-D biped gait generation method based on minimal energy control framework to keep the 10 DOFs robot walking on compliant or uneven ground stably.

PUBLICATIONS

Journal publications:

1. **Q. Zhang**, A. Myers, N. Fragnito, J. R. Franz, and N. Sharma, "Plantarflexion Moment Prediction during Walking using an sEMG-Ultrasound Imaging-Driven Neuromuscular Model", J. Neuroeng. Rehabil., 2021, (Under Review).
2. **Q. Zhang**, A. Iyer, K. Lambeth, K. Kim, and N. Sharma*, "Ultrasound Echogenicity as an Indicator of Muscle Fatigue During Functional Electrical Stimulation", Sensors, 2021, (Under review).
3. **Q. Zhang**, K. Lambeth, A. Iyer, Z. Sun, and N. Sharma*, "Ultrasound Imaging-based Closed-loop Control of Ankle Dorsiflexion by Using Functional Electrical Stimulation", IEEE Trans. Control Syst. Technol., 2021 (Under review).
4. **Q. Zhang**, A. Iyer, Z. Sun, K. Kim, and N. Sharma*, "A Dual-Modal Approach Using Electromyography and Sonomyography Improves Prediction of Dynamic Ankle Movement: A Case Study", IEEE Trans. Neural Syst. Rehabil. Eng., vol. 29, pp. 1944-1954, 2021.
5. **Q. Zhang**, W. H. Clark, J. R. Franz, and N. Sharma*, "Personalized Fusion of Ultrasound and Electromyography-Derived Neuromuscular Features Increases Prediction Accuracy of Ankle Moment during Plantarflexion," Biomed. Signal Process Control, vol. 71, pp. 103100, 2022.
6. **Q. Zhang**, A. Iyer, K. Kim*, and N. Sharma*, "Evaluation of Noninvasive Ankle Joint Effort Prediction Methods for Use in Neurorehabilitation Using Electromyography and Ultrasound Imaging," IEEE Trans. Biomed. Eng., vol. 68, no. 3, pp. 1044–1055, 2021.
7. **Q. Zhang**, K. Kim*, and N. Sharma*, "Prediction of Ankle Dorsiflexion Moment by Combined Ultrasound Sonography and Electromyography," IEEE Trans. Neural Syst. Rehabil. Eng., vol. 28, no. 1, pp. 318–327, 2020.
8. **Q. Zhang**, D. Sun, W. Qian, X. Xiao, and Z. Guo*, "Modeling and control of a cable-driven rotary series elastic actuator for an upper limb rehabilitation robot," Front. Neurorobot., vol. 14, pp. 13, 2020.
9. M. Vahidreza, **Q. Zhang**, X. Bao, and N. Sharma*, "An Iterative Learning Controller for a Switched Cooperative Allocation Strategy During Sit-to-Stand Tasks with a Hybrid Exoskeleton", IEEE Trans. Control Syst. Technol., 2021, DOI: 10.1109/TCST.2021.3089885.
10. M. Vahidreza, **Q. Zhang**, X. Bao, B. Dicianno, and N. Sharma*, "Shared Control of a Powered Exoskeleton and Functional Electrical Stimulation using Iterative Learning and Fatigue Optimization", Front. Robot. AI, 329, 2021.
11. **Q. Zhang**, Y. Wang, and X. H. Xiao*, "Effects of Ground Compliance on Bipedal Robot Walking Dynamic Property", Journal of the Chinese Society of Mechanical Engineers, 2016, 37(4): 335-342.
12. Y. Wang, **Q. Zhang**, and X. H. Xiao*, "Trajectory Tracking Control of the Bionic Joint Actuated by Pneumatic Artificial Muscle Based on Robust Modeling," ROBOT, 2016, 38(2): 248-256. (In Chinese)
13. **Q. Zhang**, X. H. Xiao*, Y. Wang, et al, "Compliant joint for biped robot considering energy consumption optimization", Journal of Central South University, 2015, 46(11): 4070-4076. (In Chinese)

In Preparation Work:

1. **Q. Zhang**, K. Kim, and N. Sharma, "Assist-as-Needed Control of a Cable-Driven Ankle exoskeleton with Ultrasound Imaging-sEMG-Based Human Volitional Intent Sensing Methodology", in preparation.
2. X. Bao, **Q. Zhang**, J. Wang, and N. Sharma, "An Investigation on Clustering-based Unsupervised Learning Method for Pennation Angle Detection from Ultrasound Imaging: A Preliminary Study", in preparation.

Conference publications and presentations:

1. **Q. Zhang**, X. Bao, N. Fragnito, M. Singh, A. Dodson, and N. Sharma*, "Ultrasound Imaging-sEMG Based Plantarflexion Assistance Control of a Cable-Driven Ankle Exoskeleton", in 2022 39th IEEE International Conference on Robotics and Automation (ICRA), IEEE, 2022 (Under Review)
2. A. Iyer, M. Singh, **Q. Zhang**, Z. Sun, and N. Sharma*, "A Reinforcement Learning Approach to Approximate Optimal Control Inputs for a Hybrid Exoskeleton with Sampled Measurements", in Proc. Amer. Control Conf., 2022 (Under Review).
3. **Q. Zhang**, K. Lambeth, A. Iyer, Z. Sun, and N. Sharma*, "Ultrasound echogenicity-based sensing and control of functional electrical stimulation to correct ankle joint dorsiflexion," In Neuroscience 2021 (Accepted)
4. **Q. Zhang**, A. Iyer, K. Lambeth, K. Kim, and N. Sharma*, "Ultrasound Echogenicity-based Assessment of Muscle Fatigue During Functional Electrical Stimulation", in 2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC), IEEE, 2021 (Accepted)
5. **Q. Zhang**, N. Fragnito, A. Myers, and N. Sharma*, "Plantarflexion Moment Prediction during the Walking Stance Phase with an sEMG-Ultrasound Imaging-Driven Model", in 2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC), IEEE, 2021 (Accepted)
6. **Q. Zhang**, A. Iyer, K. Kim*, and N. Sharma*, "Volitional contractility assessment of plantar flexors by using non-invasive neuromuscular measurements," in 2020 8th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob). IEEE, 2020, pp. 515–520.
7. A. Iyer, Z. Sheng, **Q. Zhang**, K. Kim, and N. Sharma*, "Analysis of Tremor During Grasp Using Ultrasound Imaging: Preliminary Study", in 2020 8th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob). IEEE, 2020, pp. 533–538.
8. **Q. Zhang**, A. Iyer, Z. Sun, A. Dodson, and N. Sharma*, "Sampled-Data Observer Based Dynamic Surface Control of Delayed Neuromuscular Functional Electrical Stimulation", in Dynamic Systems and Control Conference, Vol. 84270, p. V001T14A003, American Society of Mechanical Engineers, 2020.
9. **Q. Zhang**, A. Iyer, N. Sharma*, "Ultrasound based Sensing and Control of Functional Electrical Stimulation for Ankle Joint Dorsiflexion: Preliminary Study", in 2020 International Symposium on Wearable Robotics. Springer, 2020, pp. 207-311.
10. Z. Sun, X. Bao, **Q. Zhang**, K. Lambeth, and N. Sharma*, "A Tube-based Model Predictive Control Method for Joint Angle Tracking with Functional Electrical Stimulation and An Electric Motor Assist", in Proc. Amer. Control Conf., 2021, pp. 1390-1395.
11. **Q. Zhang**, Z. Sheng, F. Moore-Clingenpeel, K. Kim, and N. Sharma*, "Ankle dorsiflexion strength monitoring by combining sonomyography and electromyography," in Proc. Int. Conf. Rehabil. Robot. IEEE, 2019, pp. 240–245.
12. **Q. Zhang**, Z. Sheng, K. Kim, and N. Sharma*, "Observer design for a nonlinear neuromuscular system with multi-rate sampled and delayed output measurements," in Proc. Amer. Control Conf. IEEE, 2019, pp. 872–877.
13. V. Molazadeh, **Q. Zhang**, X. Bao, and N. Sharma*, "Neural-network based iterative learning control of a hybrid exoskeleton with an MPC allocation strategy," in Dynamic Systems and Control Conference, vol. 59148, p. V001T05A011. American Society of Mechanical Engineers, 2019.
14. **Q. Zhang**, B. Xu, Z. Guo, and X. Xiao*, "Design and modeling of a compact rotary series elastic actuator for an elbow rehabilitation robot," in Proc ICIRA. Springer, Cham, 2017, pp. 44–56.
15. **Q. Zhang**, X. Xiao*, and Z. Guo, "Power Efficiency-Based Stiffness Optimization of a Compliant Actuator for Underactuated Bipedal Robot," in Proc ICIRA. Springer, Cham, 2016, pp. 186–197.
16. **Q. Zhang**, L. Teng, Y. Wang, T. Xie, and X. Xiao*, "A study of flexible energy-saving joint for biped robots considering sagittal plane motion," in Lecture Notes in Computer Science, 2015, vol. 9245, pp. 333–344.

Patents:

1. Z. Guo, X. H. Xiao, Y. Yao, **Q. Zhang**. A Portable Elbow Exoskeleton Robot with Compliant Joint Actuator. Patent CN 106393073 B, 2018.
2. Z. Guo, X. H. Xiao, B. Y. Xu, **Q. Zhang**, D. Y. Sun. A Compliant Cable-Driven Upper Limb Exoskeleton Robot. Patent CN 107669442 A, 2018.
3. X. H. Xiao, **Q. Zhang**, D. J. Yao, et al. An Underactuated Bipedal Walking Robot Driven by Compliant Actuator. Patent CN 105599822 B, 2017.
4. X. H. Xiao, **Q. Zhang**, Y. Wang, et al. A Modular Bipedal Walking Robot with Ten Degrees of Freedom. Patent CN 104071250 A, 2014.
5. **Q. Zhang**, F. You, Y. Wang, et al. A Foot Module for Bipedal Walking Robot. Patent CN 203946189 U, 2014.
6. **Q. Zhang**, F. You, Y. Wang, et al. A Cross-shaped Joint Module for Bipedal Walking Robot. Patent CN 203946188 U, 2014.

AREAS OF TEACHING EXPERTISE

- Mechanical mechanism and mechanical design
- System dynamics / rigid body dynamics
- Linear control system / linear system theory
- Advanced feedback control
- Introduction to nonlinear control
- Adaptive control

TEACHING/MENTORING EXPERIENCE

- MEMS 1042: Mechanical Measurements 2 (Fall 2017, 60 students)
  - Teach and guide students to perform dynamics/control related experiments and record data
  - Review students' reports for each experiment
  - Hold office hours to address students' questions
- MEMS 1015: Rigid Body Dynamics (Spring 2018, 120 students)
  - Grade homework every week and grade midterm exam
  - Hold office hours to address students' questions
- Student Mentoring
  - David Hu (Undergraduate student, University of Pittsburgh)
  - Yao Peng (Undergraduate student, University of Pittsburgh)
  - Natalie Fragnito (Undergraduate student, North Carolina State University)
  - Ali Myers (Undergraduate student, North Carolina State University)
  - Claire Wiebking (Undergraduate student, North Carolina State University)
  - Jake Polar (Ph.D. student, North Carolina State University)
  - Krysten Lambeth (Ph.D. student, North Carolina State University)

HONORS AND AWARDS

- The finalist for the Best Student Paper Award at the 16th IEEE/RAS-EMBS International Conference on Rehabilitation Robotics (ICORR 2019) 2019
- The finalist for the Engineering Medical Innovation Global Competition (EMEDIC 2017) 2017
- The Second Prize of Central China Area in the 11th National Post-Graduate Electronics Design Contest 2016
- The First Prize of Interdisciplinary Youth Scholar Symposium, Wuhan University (Top 2) 2015
- The National Scholarship, Wuhan University (2%) 2015
- The First Level Academic Scholarship and Outstanding Student, Wuhan University (10%) 2015
- The First Prize of Post-Graduate Talent Competition, Wuhan University (5%) 2015

- The First Prize of the Nation in the 11th National Post-Graduate Mathematics Contest in Modeling (2.45%) 2014
- The Excellent New Post-Graduate Student Award, Wuhan University (5%) 2014
- The Outstanding Graduate, Wuhan University (15%) 2014
- The Second Prize of the Nation in the 12th Asia-Pacific Robot Contest (ABU Robocon) in China (Top 16) 2013
- The Second Prize of Wuhan University in the 6th National College Advanced Graphic Skill Competition 2013
- Two years of National Encouragement Scholarship, Wuhan University (3%) 2012, 2013
- The Second Level Scholarship and Merit Student, Wuhan University (10%) 2013
- The Second Prize of Wuhan University in the 5th National College Advanced Graphic Skill Competition 2012
- The Third Prize of Wuhan University in the 5th National College Mechanical Innovation Competition 2012
- The First Level Scholarship and Merit Student, Wuhan University (5%) 2012
- The Third Level Scholarship and Outstanding Student, Wuhan University (15%) 2011

PROFESSIONAL SKILLS

- 2-D or 3-D modeling with AutoCAD, SolidWorks, CATIA, UG, and Pro/E;
- Mechanical machining with CNC machine and 3-D printer;
- Dynamic simulation or finite element analysis with ADAMS, Matlab, and ANSYS;
- Programming with C, C#, Matlab/Simulink, and LabVIEW;
- Data processing and analyzing with SPSS, Matlab, and R;
- Human motion analysis with Vicon, Visual3D, and OpenSim;
- Other skills including MS Office, Photoshop, Visio, Dreamweaver.

PROFESSIONAL MEMBERSHIPS

- IEEE Student Member
- ASME Student Member

ACADEMIC SERVICE (JOURNAL OR CONFERENCE PAPER REVIEW)

- IEEE Transactions on Industrial Electronics
- IEEE Transactions on Cybernetics
- IEEE Transactions on Robotics
- IEEE Control System Magazine
- IEEE Transactions on Neural System and Rehabilitation Engineering
- PLOS ONE
- Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering
- IEEE Conference on Decision and Control (CDC)
- American Control Conference (ACC)
- IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)
- IEEE/RAS/EMBS International Conference on Rehabilitation Robotics (ICORR)
- IEEE/RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob)
- ASME Dynamic Systems and Control Conference (DSCC)
- IEEE Conference on Control Technology and Applications (CCTA)
- IEEE International Conference on Advanced Robotics and Mechatronics (ARM)