Haonan Peng

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RESEARCH INTERESTS

My research interests lie in the integration of robotic manipulation, control, perception, motion planning, and artificial intelligence, with a primary focus on surgical robots, addressing inaccuracies caused by cable-driven mechanisms, implementing sensorless force estimation, and developing efficient data-driven models for better close loop control and automation of surgical robots.

EDUCATION

Ph.D. Candidate in Electrical Engineering Adviser: Blake Hannaford
University of Washington (UW), Seattle, WA, BioRobotics Lab Expected 2025
Dissertation: Better Closed Loop for Cable-driven Surgical Robots - Calibration, Tracking, and Haptics

M.S. in Mechanical Engineering Adviser: Blake Hannaford
University of Washington (UW), Seattle, WA, BioRobotics Lab 09/2017-08/2019

B.S. in Mechanical Engineering
Central South University (CSU), Changsha, China 09/2012–07/2016
Thesis:

AWARDS, FUNDING, PROFESSIONAL SERVICES

- CoMotion Innovation Gap Fund (2022). Description: the fund supports proof-of-concept and go-to-market strategy activities to advance promising innovations to the next stage of commercial development and investment.
- Fenwick & West Third Place Prize, Hollomon Health Innovation Challenge (2021). Description: this competition encourages innovative solutions for big problems the world faces today related to health.
- Runner-up Best Project Award, Hamlyn Winter School on Surgical Imaging and Vision (2020). Description: an award as part of the final project presentation at Hamlyn Winter School.
- Reviewer for ICRA, ISMR, EMBC, IEEE Robotics and Automation Letters

ACADEMIC EXPERIENCE

CRTK Python Controller for RAVEN-II Surgical Robot GitHub page **09/2021–Present**
- Created a general-purpose controller code for RAVEN-II based on Collaborative Robotics Toolkit (CRTK).
- Built and tested keyboard control, go-to, trajectory follow, and random sinusoid movements.
- Currently in use across three labs and four RAVEN-II robots, having run for over 150 hours without major issues.

Sensorless Estimation of Contact Force for RAVEN-II Surgical Robot **04/2023–Present**
- Built a parallel robot system that can apply arbitrary force to RAVEN's end-effector.
- Built motor-cable units with load cell feedback that can output smooth force under passive movement.
- Developing an easy and efficient calibration process for motor locations and forces.

Efficient Learning-based Calibration for RAVEN-II Surgical Robot **09/2021–08/2023**
- Developed a calibration method for RAVEN-II's positional joints using neural networks to mitigate inaccuracies caused by cable-driven mechanisms.
- Developed regression-based calibration that meets 1000 Hz servo control loop, with comparable accuracy.

- Calibration takes less than 20 minutes, including initialization, data collection, and training of calibration models.
- RAVEN-II has calibrated accuracy with 6 times smaller errors than the previous state-of-the-art, reducing 93% error of the positional joints. The accuracy stays within 0.771˚ and 0.246 mm during 6-hour loaded operations.
- Used removal and noisy ablation study to find joint positions, velocities, and torques important to the calibration performance. Resolved homing inconsistency so that restarts require no re-calibration.

Non-invasive Continuous Blood Pressure Estimation **09/2020–Present**

- Built and tested a prototype using ECG and PPG sensors to estimate blood pressure. Developing a learning-based approach with current accuracy of ±5 mmHg compared to arterial lines.
- Collaborating with UW Medical Center and University of Minnesota to collect a database with synchronized signals of ECG, PPG, and blood pressure from operating rooms. Currently, more than 1000 OR cases are recorded in the database.

Active Synthetic Image Generator for Surgical Instrument Segmentation **07/2020–09/2021**

- Designed a blending algorithm to generate synthetic endoscopic images based on active learning, which provides training data for a CNN-based segmentation model with less concern for domain gaps.
- The segmentation model achieved comparable performance with 50% reduced usage of real images.

Neural Network Estimator for RAVEN-II Surgical Robot **08/2018–08/2019**

- Developed and tested a neural network estimator for the cable-driven surgical robot, decreasing the RMS error of the end effector's position estimation by 83.6%.
- Established a sub-mm-level visual motion tracker for RAVEN-II, using low-cost webcams, with easy calibration. Results video. This method was cited, utilized, and improved by research groups at UCB and JHU.

PUBLICATIONS

JOURNALS

J1. Reducing annotating load: Active learning with synthetic images in surgical instrument segmentation
Peng, H., Lin, S., King, D., Su, Y. H., Abuzeid, W. M., Bly, R. A., ... & Hannaford, B.
Medical Image Analysis, 97, 103246. [Link]

J2. Efficient Data-driven Joint-level Calibration of Cable-driven Surgical Robots
Peng, H., Lewis, A., Su, Y. H., Lin, S., Chiang, D., … & Hannaford, B. (2024).
Nature - npj Robotics, 2024, Accepted, in production, [arXiv]

J3. Ablation Study on Features in Learning-based Joints Calibration of Cable-driven Surgical Robots
Peng, H., Lewis, A., Su, Y. H., & Hannaford, B.
IEEE Transactions on Automation Science and Engineering, 2024, In revision, [arXiv].

J4. Automatic summarization of endoscopic skull base surgical videos through object detection and hidden Markov modeling
King, D., Adidharma, L., **Peng, H.**, Moe, K., Li, Y., Yang, Z., ... & Bly, R. A. (2023).
Computerized Medical Imaging and Graphics, 2023 [Link]

J5. Multi-Frame Feature Aggregation for Real-Time Instrument Segmentation in Endoscopic Video
Lin, S., Qin, F., **Peng, H.**, Bly, R. A., Moe, K. S., & Hannaford, B.
IEEE Robotics and Automation Letters, 6(4), 6773-6780, 2021, [Link]

J6. Local Style Preservation in Improved GAN-Driven Synthetic Image Generation for Endoscopic Tool Segmentation
Su, Y. H., Jiang, W., Chitrakar, D., Huang, K., **Peng, H.**, & Hannaford, B.
Sensors, 21(15), 5163. 2021, [Link]

CONFERENCES

C1. Real-time Data Driven Precision Estimator for RAVEN-II Surgical Robot End Effector Position
Peng, H., Yang, X., Su, Y., & Hannaford, B.
IEEE International Conference on Robotics and Automation (ICRA). 2020 [Link]

C2. Expanding the Surgical Robotics Community: An Intuitive Sim-to-Real Control Framework for Raven-II with a Budget-Friendly Gamepad Controller
Bui, M., Chalfant, N., Sun, C., Fabrega, S., **Peng, H.**, Huang, K., & Su, Y. H.
IEEE International Symposium on Medical Robotics (ISMR) (pp. 1-7), 2024 [Link]

C3. A Wearable Device For Postoperative Breast Cancer Rehabilitation With Machine Learning For Motion Tracking
Zhao, Y., Adams, C. M., Davis, T., Zhao, J., O'Rourke, N., **Peng, H.**, ... & Raiti, J
IEEE Global Humanitarian Technology Conference (GHTC) (pp. 437-440), 2022 [Link]

C4. Detection and Low-Latency Notification of Improper Backpack Posture using Deep Learning
Hung, H. Y., Millaway, G., Mustafa, S., **Peng, H.**, Geiger, A., & Raiti, J.
IEEE Global Humanitarian Technology Conference (GHTC) (pp. 433-436), 2022 [Link]

PATENTS

P1. Cable-Driven Force Actuation System
Peng, H., Chiang, D., Hendricks, J., Shing, J., Feng, H., Lewis, A., Su, Y. H., Hannaford, B.
US provisional patent application (2024), MBHB Ref. 24-1522-US-PRO

P2. Prediction of Hemodynamic Parameters from Sensor Data Using Machine Learning
Hou, Y., **Peng, H.**, Jense, R., Reinhall, P., Johnson, M.
US provisional patent application (2024), UW Ref. 49629

P3. Preprocessing of Sensor Data for Input to Machine Learning Model
Hou, Y., **Peng, H.**, Jense, R., Reinhall, P., Johnson, M.
US provisional patent application (2024), UW Ref. 50155

PRESENTATIONS

- Introduction to RAVEN Surgical Robot, ControlX Seminar, 10/11/2024, Seattle, WA
- ICRA 2020, 05/31/2020, Virtual

TEACHING AND MENTORSHIP EXPERIENCE

TEACHING

Instructor, ECE Department, UW 01/2023-03/2023
- EE 543 - Models Of Robot Manipulation, a graduate-level course that covered homogeneous transformation, forward & inverse kinematics, Jacobian matrix, motion planning, and teleoperation.
- Created 300+ lecture slides for 10-week lectures associated to the textbook. Link to lecture slides.
- Developed a project that guides students to build robot arms using servo motors and apply Cartesian control.

Teaching Assistant, UW
Techin 517 – Robotics Lab 2 03/2023-06/2023, 03/2024-06/2024
- a graduate-level project-based course, in which VR perception, real-world navigation, and manipulation of a Fetch robot were developed.
- Prepared and led lab sections of the Fetch robot, including base & arm control, navigation & SLAM, and motion planning, utilizing Gazebo, RViz, and MoveIt. GitHub page.

Techin 512 - Introduction To Sensors And Circuits 2020-2024

- Developed sensor lab based on PPG. Led labs including circuit analysis and sensor implementation.

EE 241 - Programming For Signal And Information Processing Applications 01/2024-03/2024

Techin 515 – Hardware/Software Lab 2 01/2022-03/2022

Techin 514 – Hardware/Software Lab 1 01/2022-03/2022

EE 441 - Control System Analysis I 09/2020-12/2020, 03/2021-06/2021

MENTORSHIP

- Dun-Tin Chiang, M.S., UW; 2023-, Cable-driven force actuation system, Publication: J2, Patent: P1
- Jared Shing, M.S., UW; 2023-, Python controller for RAVEN-II surgical robot, Patent: P1
- Jordan Hendricks, M.S., UW: 2023-, Controller for cable-driven force actuation system, Patent: P1
- Haokun Feng, M.S., UW; 2023-, Cable-driven force actuation system (optimal motor location), Patent: P1
- Qiana Chen, M.S., UW; 2024-, Customer discovery for non-invasive blood pressure device
- Armina Moghadasi, B.S., UW; 2024-, Cable-driven force actuation system (mechanical design)
- Wenfan Jiang, M.S., University of Michigan; 2023, Reinforcement learning on coverage trajectory, Publication: J2
- Matthew Klein, M.S., UW, 2023, ROS2 for RAVEN-II
- Helen Lai, B.S., UW, 2023, PCB design for RAVEN-II external joint encoders, Publication: J2
- Yifang Hou, M.S., 2022-2023, Non-invasive continuous blood pressure estimation, Patent: P2, P3
- Tintin Zhang, M.S., UW, 2022-2023, Business research for continuous blood pressure
- Boyang Li, B.S., UW, 2024-, Simulation of RAVEN-II with real control API

START-UP

Co-founder, Pressurge Inc **08/2024–Present**

- A start-up aims to commercialize AI-based non-invasive blood pressure monitoring device for operating rooms.
- Collaborating with UW CoMotion, UW Medical Center, UW Department of Mechanical Engineering, and University of Minnesota.
- Currently under negotiations with venture companies

LEADERSHIP AND VOLUNTEERING EXPERIENCE

President of Student Union, College of Mechanical and Electrical Engineering, CSU **09/2013–09/2015**

- Chaired the student union with 8 departments and 118 members
- Organized the graduation ceremony and science & technology festival of the department

34th CSU Volunteer Teaching in Zuojialong District, CSU **09/2014–12/2014**

- Organized and participated in this event, in which students of CSU provided volunteering tutoring for primary and middle school students in local area

Undergrad Counselor Intern, College of Mechanical and Electrical Engineering, CSU **09/2015–04/2016**

- Provided academic, mental, and safety counseling to undergraduate students
- Supervised the student union and provided training on news and reports writing

SKILLS

Robotics: Robot manipulation, serial/parallel kinematics & dynamics, robot testing, robot maintenance, Robot Operating System (ROS), Gazebo, RViz, MoveIt, robot navigation, localization & mapping

Coding: Python, C++, MATLAB

Machine Learning: TensorFlow, Keras, PyTorch, scikit-learn, Pandas

Mechanical Engineering: SolidWorks, ADAMS, AutoCAD, finite element analysis

Perception: Encoder, strain gauge, load cell, infrared sensor, computer vision

Prototyping: Arduino, Raspberry Pi, ESP 32, 3D printing, manual and oven soldering