BIOGRAPHICAL SKETCH

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NAME: Kennedy III, Monroe

eRA COMMONS USER NAME (credential, e.g., agency login):

POSITION TITLE: Assistant Professor of Mechanical Engineering

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE (if applicable)	END DATE MM/YYYY	FIELD OF STUDY
University of Maryland Baltimore County	BS	05/2012	
University of Pennsylvania	MS	05/2016	
University of Pennsylvania	PHD	05/2019	

A. Personal Statement

I direct the Assistive Robotics and Manipulation Laboratory (ARMLab) at Stanford University. The research focus of the lab is to develop collaborative robots defined as robots capable of working closely with and for human teammates. To accomplish this our research has two primary thrusts, first we develop algorithms that allow collaborative robots to reason about the way the robot must behave, the complexity of the task, and a model of human behavior in order to accomplish a mutual goal with the human teammate. This first thrust requires the use of machine learning, dynamic system modeling, and control in order to enable the robotic system to be an effective partner. This thrust has many applications that range from human-robot cooperative transport, to improving the efficiency of a human teaching a robot a new task (Learning from Demonstration), to assistive robotic applications for wearable robotic platforms capable of observing the environment, the human and taking action that enables the humans intent or provides safety to the human. These thrusts in assistive robotic applications include a fall prevention sensor capable of observing a human wearer's path, gait and torso motion and predicting their future stability while walking conditioned on the surrounding environment. In addition, it includes work in Intelligent Upper Limb Prosthetics which is the focus of this proposal, which enables a prosthetic to receive underactuated input from a human user (inputs that are not sufficient to prescribe the full range of motion possible for the robot prosthetic) and conditioned on the task and environment, leverage autonomy to enable the humans intended action. The second research thrust in the ARMLab is improving robotic manipulation. This is important as a catalyst to enable collaborative robots to be more capable in human-based environments. Our latest work involves advancing robotic fingertip sensing towards dexterous manipulation tasks. Our sensor uses computer vision to observe the interior of a transparent robotic fingertip to the contact boundary for estimation of contact shape and surface forces. Our approach allows for the calibration of both shape and forces at a high resolution and will serve to improve the skill transfer of robotic manipulation to new dexterous tasks. The goals of this study are to advance our work in intelligent prosthetics which leverage robotic autonomy to cover the gap between human underactuated input and the necessity of complex, dexterous manipulation needed in Activities of Daily Living (ADLs). Our proposed platform will be capable of taking a range of inputs from surface electromyography sensors (EMG) to a range of brain-computer interfaces (BCI) and gaze tracking from the human in order to control the robot. While there have been significant advances in these sensors, powered prosthesis can have many degrees of freedom (DOF) joints that must be controlled, and methods of direct low-level control for the human have proven burdensome and in some cases impossible. Robotic autonomy allows for a paradigm where the human provides a signal to the robot through the aforementioned inputs, observe the environment to provide further semantic context, and the robot can verify user intended action through methods like Augmented Reality (AR) in head-mounted displays, and perform the complex task on the human's behalf. This intelligence will be deployed on a virtual prosthetic arm displayed in AR as well as on a physical manipulator through teleoperation. Additionally, the integration with the ARMLab DenseTact sensor will enable the physical platform to sense shape and forces within the task, and this information will be displayed to the user through haptic interfaces for dexterous control, agency, and improved embodiment. Solutions for this work are applicable both for amputees as well as those with paralysis who leverage teleoperation.

1. Do W, Jurewicz B, Kennedy M. DenseTact 2.0: Optical Tactile Sensor for Shape and Force Reconstruction. 2023 IEEE International Conference on Robotics and Automation (ICRA). 2023 IEEE International Conference on Robotics and Automation (ICRA); ; London, United Kingdom. IEEE; c2023. Available from: https://ieeexplore.ieee.org/document/10161150/ DOI: 10.1109/ICRA48891.2023.10161150
2. Wang W, Raitor M, Collins S, Liu C, Kennedy M. Trajectory and Sway Prediction Towards Fall Prevention. 2023 IEEE International Conference on Robotics and Automation (ICRA). 2023 IEEE International Conference on Robotics and Automation (ICRA); ; London, United Kingdom. IEEE; c2023. Available from: https://ieeexplore.ieee.org/document/10161361/ DOI: 10.1109/ICRA48891.2023.10161361
3. Ng E, Liu Z, Kennedy M. It Takes Two: Learning to Plan for Human-Robot Cooperative Carrying. 2023 IEEE International Conference on Robotics and Automation (ICRA). 2023 IEEE International Conference on Robotics and Automation (ICRA); ; London, United Kingdom. IEEE; c2023. Available from: https://ieeexplore.ieee.org/document/10161386/ DOI: 10.1109/ICRA48891.2023.10161386

B. Positions, Scientific Appointments and Honors

Positions and Scientific Appointments

2021 -	Assistant Professor (by courtesy) of Computer Science, Stanford University, PALO ALTO, CA
2019 -	Assistant Professor of Mechanical Engineering, Stanford University, PALO ALTO, CA
2019 - 2019	Technical Staff, MIT Lincoln Laboratory, Lexington, MA

Honors

2022 - 2027	Faculty Early Career Development Award, (FRR-CMMI), National Science Foundation
2013 - 2018	Graduate Research Fellowship, National Science Foundation

C. Contribution to Science

1. Dexterous Manipulation for robots is the catalyst problem to having robots capable of existing ubiquitously with human counterparts. To be effective, robots must be able to leverage tactile interaction to explore, model and predict expected outcomes of manipulation for complex tasks. This project works on improving robotic manipulation through the improvement of robotic fingers, then using these novel sensors to improve robotic manipulation algorithms necessary for complex dexterous manipulation tasks.

   a. Do W, Jurewicz B, Kennedy M. DenseTact 2.0: Optical Tactile Sensor for Shape and Force Reconstruction. 2023 IEEE International Conference on Robotics and Automation (ICRA). 2023 IEEE International Conference on Robotics and Automation (ICRA); ; London, United Kingdom. IEEE; c2023. Available from: https://ieeexplore.ieee.org/document/10161150/ DOI: 10.1109/ICRA48891.2023.10161150
   b. Do W, Kennedy M. DenseTact: Optical Tactile Sensor for Dense Shape Reconstruction. 2022 International Conference on Robotics and Automation (ICRA). 2022 IEEE International Conference on Robotics and Automation (ICRA); ; Philadelphia, PA, USA. IEEE; c2022. Available from: https://ieeexplore.ieee.org/document/9811966/ DOI: 10.1109/ICRA46639.2022.9811966
   c. Mucchiani C, Kennedy M, Yim M, Seo J. Object Picking Through In-Hand Manipulation Using

Passive End-Effectors With Zero Mobility. IEEE Robotics and Automation Letters. 2018; 3(2):1096-1103. Available from: https://ieeexplore.ieee.org/document/8264776/ DOI: 10.1109/LRA.2018.2795652

2. In this project we develop a torso worn sensor that consists of cameras and inertial measurement units (IMUs) capable of observing a human wearer's trajectory (where they have walked, their gait and torso motion), and predicting their future motion conditioned on the surrounding environment. Using machine learning techniques, we are able to inform a model on the past trajectory of the user, and based on an efficient representation of surrounding obstacles (depth panorama image) we are able to predict multi-hypothesis future trajectories with lookahead time horizons of a few seconds, and if instability is predicted over a path of high likelihood, we alert the user to warn them of the expected instability, therefore reducing the risk of falling.

    a. Wang W, Raitor M, Collins S, Liu C, Kennedy M. Trajectory and Sway Prediction Towards Fall Prevention. 2023 IEEE International Conference on Robotics and Automation (ICRA). 2023 IEEE International Conference on Robotics and Automation (ICRA); ; London, United Kingdom. IEEE; c2023. Available from: https://ieeexplore.ieee.org/document/10161361/ DOI: 10.1109/ICRA48891.2023.10161361

3. In this work, we developed a robotic platform capable of pouring from open containers. The application of this system is a robot capable of working alongside a human collaborator in a wet lab, by performing mixing tasks when the task is either laborious or potentially dangerous for the human to perform. It is desirable that the robot not require specialized tools to assist, and requires minimal environment adaption for its operation. This work combines tactile and computer vision in order to successfully pour from open containers quickly and accurately.

    a. Kennedy M, Schmeckpeper K, Thakur D, Jiang C, Kumar V, Daniilidis K. Autonomous Precision Pouring From Unknown Containers. IEEE Robotics and Automation Letters. 2019; 4(3):2317-2324. Available from: https://ieeexplore.ieee.org/document/8653969/ DOI: 10.1109/LRA.2019.2902075
    b. Kennedy M, Queen K, Thakur D, Daniilidis K, Kumar V. Precise dispensing of liquids using visual feedback. 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS); ; Vancouver, BC. IEEE; c2017. Available from: http://ieeexplore.ieee.org/document/8202301/ DOI: 10.1109/IROS.2017.8202301