http://leegilwoo.com

GILWOO LEE

gilwoo301@gmail.com

Robotics / Machine Learning Research Scientist

My primary research interest is to enable robots to acquire diverse skills under uncertainty. Such skill acquisition requires huge amounts of data and entails risks of damaging robots. I have shown that Bayesian reinforcement learning can be used to expedite learning and result in robust, uncertainty-aware skill acquisition. In addition, I am interested in human-robot interaction for people with disabilities. Through a number of research threads in autonomous assistive feeding project, I have seen how robots can empower people with disabilities to regain control over external environments. I believe that robots can become more useful and practical tools by enabling them to safely interact with and around humans.

EDUCATION

2017–PRESENT **PhD Student in School of Computer Science, UNIVERSITY OF WASHINGTON, Seattle, WA**

Advisor Siddhartha S. Srinivasa (Boeing Endowed Professor)

Thesis *Scalable Bayesian Reinforcement Learning* (Tentative, TBD)

Committee Siddhartha S. Srinivasa, Byron Boots, Debadeepta Dey, Sam A. Burden

2015–2017 **MS in Robotics Institute, CARNEGIE MELLON UNIVERSITY, Pittsburgh, PA**

Advisors Matthew T. Mason, Siddhartha S. Srinivasa

Thesis *GP-ILQG: Data-driven Robust Optimal Control for Uncertain Nonlinear Dynamical Systems*

Committee Matthew T. Mason, Siddhartha S. Srinivasa, Geoffrey J. Gordon

2014–2015 **MEng in Computer Science, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, MA**

Advisors Leslie P. Kaelbling, Tomás Lozano-Peréz

Thesis *Hierarchical planning for multi-contact non-prehensile manipulation*

2006–2010 **BS in Computer Science and Mathematics (double major), MIT, Cambridge, MA**

Advisors Leslie P. Kaelbling (Computer Science), Richard P. Stanley (Math)

AWARDS & HONORS

2015–2020 **KWANJEONG EDUCATIONAL FOUNDATION FELLOWSHIP**

5-year scholarship for PhD students, one of forty awardees

2016–2017 **PRESIDENTIAL FELLOWSHIP, CMU SCHOOL OF COMPUTER SCIENCE**

2015 **BEST CONFERENCE PAPER FINALIST,** IEEE/RSJ INTERNATIONAL CONFERENCE ON INTELLIGENT ROBOTS AND SYSTEMS

For the paper titled "Hierarchical planning for multi-contact non-prehensile manipulation"

2006–2010 **SAMSUNG SCHOLARSHIP,** ONE OF TEN UNDERGRADUATE AWARDEES

4-year scholarship for Korean students studying abroad

RESEARCH EXPERIENCES

2018–PRESENT **Research Associate, University of Washington**

The Curious Minded Machine: Curiosity is widely recognized as a fundamental mode of cognition and is particularly critical during childhood development. Developing intelligent robots with a sense of "curiosity" may lead to an important breakthrough in artificial intelligence: agents that proactively expand their knowledge and capabilities by themselves through information-generation. We propose a principled Bayesian reinforcement learning (BRL) framework that incorporates a mathematically elegant way to model curiosity. We show that BRL yields naturally curious behaviors that benefit long-term task performance. I have been the main research scientist for BRL algorithms. This project is collaboration among University of Washington, CMU, University of Pennsylvania, MIT, and Honda Research Institute USA.

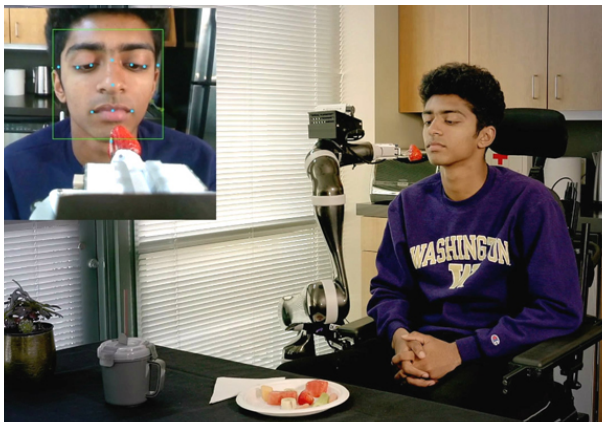
MEDIA APPEARANCE "Curious about whether robots can be curious? University of Washington joins initiative to find out," GeekWire, Oct. 25, 2018.

Publications See [5], [10] in the publications list. Several invited talks in conferences and research symposiums.

2020–Present **Scalable, Adaptive, and Resilient Autonomy (SARA):** SARA is a research collaboration with U.S. Army Research Laboratory's Combat Capabilities Development Command (CCDC). We work on increasing the operational tempo and mobility of autonomous ground systems to traverse complex off-road environments. I am coordinating a team of 4 Principal Investigators, 8 PhD students, and 1 Postdoc and integrating a new anytime motion planning algorithm (Generalized Lazy Search). We will be participating in a two-week experimentation event in Oct 2020, at Base Camp Lejeune in North Carolina.

Off-Road Autonomous Maneuver of a Combat Vehicle

2017–Present **Food Manipulation for Assistive Feeding:** Eating is an activity of daily living (ADL) and losing the ability to self-feed can be devastating. Eating free-form food is one of the most intricate manipulation tasks we perform everyday, demanding robust non-prehensile manipulation of a deformable hard-to-model target. Through this project, we develop algorithms and technologies towards a robotic system that can autonomously feed people with upper-extremity mobility limitations. I have been the main developer of the motion planning stack and have designed and implemented bite-picking strategies.



The assistive robot, ADA, delivers honeydew to the person sitting on the wheelchair.

Media Appearance "Robots that feed people who can't feed themselves are here," FastCompany, Mar. 13, 2019.
"Assistive robot learns to feed," U.S. National Institutes of Health, April 10, 2019.
(Others: BBC News, BBC World News, Reuters, GeekWire, Futurism, labroots,, New Atlas, Wonderful Engineering, Interesting Engineering, Digital Trends, Science Daily, Futurity, UW News)

Relevant Publications See [1], [4], [11], [13], [14] in the publications list. First author in one conference paper and one workshop paper. Second author in a journal publication and one dataset publication.

2018–2020 **Manipulation in Cluttered Spaces:** This project is supported by US Army Research Laboratory (ARL)'s Robotics Collaborative Technology Alliance (RCTA), which aims to "bring together government, industrial, and academic institutions to address research and development required to enable the deployment of future military unmanned ground vehicle systems ranging in size from man-portables to ground combat vehicles." Four key technology areas expected to be critical to the development of future autonomous systems: Perception, Intelligence, Human-Robot Interaction, and Dexterous Manipulation and Unique Mobility (DMUM). Our team has been in charge of DMUM and the integration of all components. We have developed a motion planning stack for a mobile manipulation platform ROMAN. The goal for this robot is to clear a pile of heavy debris autonomously. I have been in charge of risk-sensitive motion planners.

ROMAN picks up a piece of wooden branch from cluttered debris.

This project is an ongoing collaboration among ARL, CMU, Florida State University, General Dynamics Land Systems, Jet Propulsion Laboratory, MIT, QinetiQ North America, University of Central Florida, and UPenn.

Media Appearance

My role in the RCTA project was interviewed and the video clip was shown in the RCTA Capstone Meeting held in Pittsburgh, PA in Nov 2019. The interview was to be used only within ARL and thus there is no public footage available. I mainly discussed how I have developed the motion planning stack to be risk-sensitive and how it integrates costly sensing in data-efficient manner, and what it was like to collaborate with ARL.

Publications

See [2], [12] in the publications list.

2017–2018

Human-Robot Handover: Human-robot collaboration can enable humans to work on safe and less physically demanding tasks while robots take care of risky and heavy-payload tasks. In order for humans and robots to collaborate safely and swiftly, robots need to understand human intentions and act in a way that is predictable and legible from human perspective. We have proposed a unified generative model of human reaching motion that allows the robot to infer human intent and plan legible motions. Our study on human reaching motion reveals that elliptical motion model yields a good fit to empirical data. I have analyzed the collected user study data and implemented legible robot motions.

Human-to-robot handover in a shared-workspace collaboration

Publications

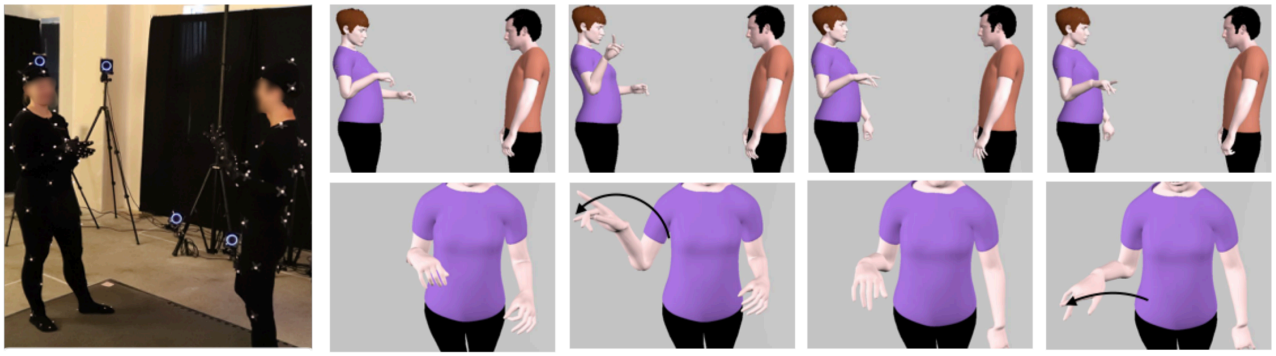
See [6] in the publications list.

2017–2019

Ph.D. Research Intern & Part-time Research Consultant, Facebook Reality Lab

Learning Human Gestures and Synthesizing Real-time Finger Motions: To work in uncertain environments with humans, robots must understand how humans behave and communicate. Human behavior involves the highly structured, multi-channel coordination of gaze, gesture, verbal and facial movements. To address the challenge of interpreting human gestures, we have collected a multimodal, wholistic dataset of people having social interaction captured with a motion capture system, which amounts to 16.2M frames. This is the largest dataset available. The statistical analysis verifies strong intraperson and interperson covariance of arm, hand, and speech features, potentially enabling new directions on data-driven social behavior analysis, prediction, and synthesis. We further demonstrate the use of this dataset to synthesize finger motions aligned with speech.

I have been the lead developer and research scientist on this project.

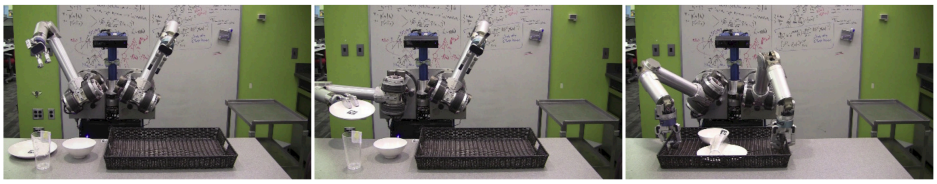


The dataset collected on social interaction (left) has been used to generate real-time finger motions (right).

Publications See [3] in the publications list. First author.

2015–2017 **Research Associate, Carnegie Mellon University**

Multi-step Mobile Manipulation with Error-recovery: Household manipulation presents a challenge to robots because it requires perceiving a variety of objects, planning multi-step motions, and recovering from failure. In collaboration with Toyota Motor Engineering & Manufacturing North America, we have worked on practical practical techniques that improve performance in these areas by considering the complete system in the context of this specific domain. We validate these techniques on a table-clearing task that involves loading objects into a tray and transporting it. The results show that these techniques improve success rate and task completion time by incorporating expected real-world performance into the system design. I was in charge of error detection and recovery and empirical evaluation of the overall system.



HERB performing a table-clearing task via sequential motion planning

Publications See [7] in the publications list. This work was presented in SIMPAR 2016 and RSS 2016 as invited talks.

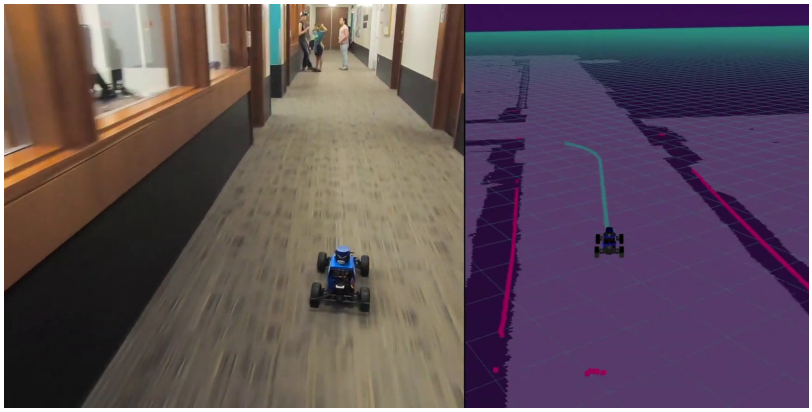
Robotics Projects

2017–Present **AIKIDO**: AIKIDO is a C++ library, complete with Python bindings, for solving robotic motion planning and decision making problems. This library is tightly integrated with DART for kinematic/dynamics calculations and OMPL for motion planning. AIKIDO optionally integrates with ROS for execution on real robots. AIKIDO is currently being used across multiple labs and projects including University of Washington, Carnegie Mellon University, University of Southern California, and Robotics Collaborative Technology Alliance (RCTA, sponsored by US Army Research Laboratory).

I am one of the lead developer and maintainer of the library.

2018–Present **MuSHR**: Our goal is to democratize robotics with MuSHR, the Multi-agent System for non-Holonomic Racing. We are developing a low-cost racecar platform with open-source software, tutorials, and class assignments. We want anyone from high school students to Ph.D. researchers to be able to learn about and perform research in robotics. Each MuSHR racecar is fitted with a full-suspension base, IMU, NVIDIA Jetson TX2, YDLIDAR laser scanner, and Intel RealSense RGBD camera. We have over 20 racecars in our fleet.

I have been mainly in charge of developing motion planners to be used in undergraduate coursework, setting up an optical motion capture system for real-time state estimation, and setting up simulation pipeline for reinforcement learning.



MuSHR navigating through corridors with real-time motion planning and collision detection

2017–Present **ADA**: ADA, the Assistive Dextrous Arm, mimics equipment used in real homes by people with mobility impairments. It consists of a Kinova JACO robotic arm mounted on a powered ROVI Mobility wheelchair. It is the main platform for our research thrust on robot-assisted feeding for people with upper-extremity impairments. The arm has 2 fingers, a custom tactile sensor, and Intel RealSense D415 to wirelessly transmit RGBD video. I have been in charge developing the motion planning and perception components. I have collaborated with Prof. Stefanos Nikoladais at University of Southern California for setting up an undergraduate class using the same robot.

ADA's feeding system is being tested by users with mobility impairments

2015–Present **HERB:** HERB**,** the Home Exploring Robot Butler, serves as the realistic testbed for all of our algorithms and as a focal point of our industry and academic collaborations. It is a bimanual mobile manipulator comprised of two Barrett WAM arms on a Neobotix base. It is equipped with a suite of image and range sensors, including the Carnegie Robotics MultiSense SL and Intel RealSense. I have been mainly in charge of designing the 3rd generation of HERB and maintaining its perception and control pipelines.

Democratic presidential candidate Hillary Clinton, left, talks with Professor Siddhartha Srinivasa as he describes a robotic arm (HERB) during a tour of a Robotics Lab at Carnegie Mellon University on a campaign stop, Wednesday, April 6, 2016, in Pittsburgh. (AP Photo/Keith Srakocic)

Media Appearance
"University of Washington's HERB robot makes cameo on X-Files as automated sushi waiter," GeekWire, March 2, 2018.

"Clinton hits Sanders on gun control, sharpens attacks", Business Insider, Apr. 6, 2016.

"Movie review: 'Robots' like you have never seen them before", Pittsburgh Post-Gazette, Sep. 3, 2015.

2015–2017 **PrPy**: PrPy is a Python library developed and maintained by the Personal Robotics Laboratory at UW. This library includes robot-agnostic utilities that make it easier to use OpenRAVE in Python scripts. This includes a high-level planning pipeline, helper functions, and visualization tools. This library has been used across multiple labs and projects at University of Washington and CMU. I am one of the main developers.

Teaching

Winter 2020 **Autonomous Robotics, University of Washington, Seattle, WA**

Assisted in designing and instructing an undergraduate course on autonomous robots. Students covered a range of topics in perception, planning and control as well as implemented algorithms on a fleet of 1/10th sized rally cars. (Link to course)

Spring 2019 **Mobile Robots, University of Washington, Seattle, WA**

Assisted in designing and instructing an undergraduate course on mobile robots. Mentored group projects, designed and graded assignments. (Link to Course)

Spring 2017 **Robot Autonomy, Carnegie Mellon University, Pittsburgh, PA**

Graduate-level course in motion planning and control. Mentored group projects and led recitations.

Spring 2014, Fall 2014, Spring 2015 **Elements of Software Construction, Massachusetts Institute of Technology, Cambridge, MA**

One of the largest undergraduate courses for computer science majors. Led recitations, mentored group projects, and managed assignments for over 200 students each semester.

Advising

2018–Present Nansong Yi (MS, University of Washington), Ryan Feng (PhD, University of Michigan), Kyle Zhang (Undergraduate, University of Washington), Rishabh Madan (Undergraduate, India Institute of Technology)

2014–2015 **Undergraduate Student Advisory Group (USAGE) in MIT EECS**
USAGE provides critical student input to the department leadership group, helping guide curriculum development; develops a role for undergraduate students in faculty search; and shapes IAP activities.

Service

Organizer RSS 2017 Workshop on (Empirically) Data-Driven Manipulation

Reviewer The International Journal of Robotics Research (IJRR)

The IEEE Robotics and Automation Letters (IEEE RA-L)

The IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)

The IEEE International Conference on Robotics and Automation (ICRA)

Robotics: Science and Systems (RSS)

The International Symposium on Experimental Robotics (ISER)

The IEEE International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR)

Invited Talks

2019 **Bayesian Reinforcement Learning for Sim2Real**
Robotics: Systems and Science Conference (RSS) 2019

Workshop on Closing the Reality Gap in Sim2real Transfer for Robotic Manipulation

2019 **Robust Manipulation with Bayesian Reinforcement Learning**

RSS Conference 2019

Workshop on Challenges in Manipulation

2019 **Scalable Bayesian Reinforcement Learning with Experts**
RSS Conference 2019
Workshop on Combining Learning and Reasoning – Towards Human-Level Robot Intelligence

2018 **Reinforcement Learning under Uncertainty**
Amazon Research Awards Fall Symposium 2018

2017 **Challenges in Non-Prehensile Manipulation**
IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2017
Workshop on Development of Benchmarking Protocols for Robot Manipulation

2016 **GP-ILQG: Data-driven Robust Optimal Control for Sim-to-Real Challenges**
IEEE International Conference on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR) 2016
Workshop on Sim2Real Challenges

Publications

Link to Google Scholar

M.S. Thesis **GP-ILQG: Data-driven Robust Optimal Control for Uncertain Nonlinear Dynamical Systems**
Carnegie Mellon University, 2017.

M.Eng Thesis **Hierarchical planning for multi-contact non-prehensile manipulation**
Massachusetts Institute of Technology, 2019.

Journal Publications **[1] Towards Robotic Feeding: Role of Haptics in Fork-Based Food Manipulation**
Tapomayukh Bhattacharjee, Gilwoo Lee, Hanjun Song and Siddhartha. S. Srinivasa, "Towards Robotic Feeding: Role of Haptics in Fork-Based Food Manipulation,"
In IEEE Robotics and Automation Letters, vol. 4, no. 2, pp. 1485-1492, April 2019.
Citation: 17

Conference Publications **[2] Posterior Sampling for Anytime Motion Planning on Graphs with Expensive-to-Evaluate Edges**
Brian Hou, Sanjiban Choudhury, Gilwoo Lee, Aditya Mandalika, Siddhartha S. Srinivasa
To appear in International Conference on Robotics and Automation (ICRA). 2020.

[3] Talking With Hands 16.2M: A Large-Scale Dataset of Synchronized Body-Finger Motion and Audio for Conversational Motion Analysis and Synthesis
Gilwoo Lee, Zhiwei Deng, Shugao Ma, Takaaki Shiratori, Siddhartha S. Srinivasa, Yaser Sheikh
International Conference on Computer Vision (ICCV). 2019.
(25% acceptance rate)

[4] Robot-Assisted Feeding: Generalizing Skewering Strategies across Food Items on a Plate
Gilwoo Lee, Ryan Feng, Youngsun Kim, Ethan K. Gordon, Matt Schmittle, Shivaum Kumar, Tapomayukh Bhattacharjee, Siddhartha S. Srinivasa
International Symposium on Robotics Research (ISRR). 2019.
Citation: 3

[5] Bayesian Policy Optimization for Model Uncertainty
Gilwoo Lee, Brian Hou, Aditya Vamsikrishna, Jeongseok Lee, Sanjiban Choudhury, Siddhartha S. Srinivasa
International Conference on Learning Representations (ICLR). 2019.
(31.4% acceptance Rate)
Citation: 10

[6] A Study of Reaching Motions for Collaborative Human-Robot Interaction
Sara Sheikholeslami, Gilwoo Lee, Justin W. Hart, Siddhartha Srinivasa, Elizabeth A. Croft
In International Symposium on Experimental Robotics (ISER). 2018.

[7] A System for Multi-Step Mobile Manipulation: Architecture, Algorithms, and Experiments
Siddhartha S. Srinivasa, Aaron M. Johnson, Gilwoo Lee, Michael C. Koval, et. al.
International Symposium on Experimental Robotics (ISER). 2016.
Citation: 4

[8] Hierarchical planning for multi-contact non-prehensile manipulation
Gilwoo Lee, Tomas Lozano-Pérez and Leslie P. Kaelbling
IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Hamburg, 2015, pp. 264-271.
(46% acceptance rate, Finalist for Best Conference Paper Award)
Citation: 29

Workshop Publications

[9] Towards Effective Human-AI Teams: The Case of Collaborative Packing
Gilwoo Lee, Christoforos Mavrogiannis, Siddhartha S. Srinivasa
Symposium on Artificial Intelligence for Human-Robot Interaction, 2019 AAAI Fall Symposium Series.

[10] Residual Bayesian Q-Learning for Meta-Reinforcement Learning with Experts
Gilwoo Lee, Sanjiban Choudhury, Brian Hou, Siddhartha S. Srinivasa
Workshop on Combining Learning and Reasoning – Towards Human-Level Robot Intelligence
Robotics: Systems and Science, 2019.
(Selected for Contributed Talk)

[11] Bite Acquisition of Soft Food Items via Reconfiguration
Gilwoo Lee, Tapomayukh Bhattacharjee, Siddhartha S. Srinivasa
Workshop on Task-Informed Grasping (TIG-II): From Perception to Physical Interaction
Robotics: Systems and Science, 2019.

[12] GP-ILQG: Data-driven Robust Optimal Control for Uncertain Nonlinear Dynamical Systems
Gilwoo Lee, Siddhartha S. Srinivasa, Matthew T. Mason
Workshop on (Empirically) Data-Driven Manipulation.
Robotics: Systems and Science, 2017.
Citation: 12

Dataset

[13] A Dataset of Bite Acquisition Attempts on Solid Food Using Different Manipulation Strategies
Ethan K. Gordon, Gilwoo Lee, Ryan Feng, Youngsun Kim, Matt Schmittle, Shivaum Kumar, Tapomayukh Bhattacharjee, Siddhartha S. Srinivasa, 2019, https://doi.org/10.7910/DVN/8A1XO3, Harvard Dataverse, V1.
(13,628 downloads)

[14] A Dataset of Food Manipulation Strategies
Tapomayukh Bhattacharjee, Gilwoo Lee, Hanjun Song, Siddhartha S. Srinivasa, 2018, https://doi.org/10.7910/DVN/8TTXZ7, Harvard Dataverse, V15.
(36,853 downloads)