**Jaskaran Singh Grover**

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**Research Interests**

Nonlinear Control, Optimization, Motion Planning, Multirobot Systems, System Identification, Deep Learning

**Education**

2018-Current **Carnegie Mellon University**

PhD. Student in Robotics. GPA 4.00 (Advisors: Prof. Katia Sycara and Prof. Changliu Liu)

2016-2018 **Carnegie Mellon University**

Master of Science in Robotics. GPA 4.00 (Advisors: Prof. Howie Choset and Dr. Matthew Travers)

2015-2016 **University of California, Los Angeles**

Master of Science in Electrical Engineering. GPA 3.97

2010-2014 **Birla Institute of Technology and Science, Pilani, India**

Bachelor of Engineering in Electronics and Instrumentation (Distinction) GPA 9.00/10

**Skills**

ROS, Python, C, C++, TensorFlow, Keras

MATLAB, Simulink, Mathematica, Solidworks, Open-CV, COMSOL Multiphysics, NI LabVIEW

**Relevant Coursework**

Convex Optimization, Robust and Optimal Control, Kinematics and Dynamics, Linear Systems, Underactuated Robotics, Deep Learning, Machine Learning, Linear Systems, Adaptive Filtering, Deep Reinforcement Learning, Math fundamentals for Robotics

**Papers**

* **Jaskaran Grover**, Changliu Liu, Katia Sycara, “Parameter Identification for Multirobot Systems: A Duality Perspective” (In preparation)
* **Jaskaran Grover**, Changliu Liu, Katia Sycara, “Why Does Symmetry Cause Deadlocks?” (IFAC World Congress 2020)
* **Jaskaran Grover**, Changliu Liu, Katia Sycara, “Deadlock Analysis and Resolution in Multirobot Systems” (WAFR 2020)
* K. Shih, C. Ho, **Jaskaran Grover**, C. Liu, S. Scherer, “Provably Safe in the Wild: Testing Control Barrier Functions on a Vision Based Quadrotor in Outdoor Environments” (RSS 2020 Workshop on Robust Autonomy)
* **Jaskaran Grover**, Daniel Vedova, Nalini Jain, Howie Choset, Matthew Travers, “Motion Planning, Design Optimization and Fabrication of Ferromagnetic Swimmers”, (RSS 2019)
* Scott Kelly, Rodrigo Abrajan, **Jaskaran Grover**, Howie Choset, Matthew Travers, “Planar Motion Control, Coordination and Dynamic Entrainment in Chaplygin Beanies”, (DSCC 2018)
* Chaohui Gong, Julian Whitman, **Jaskaran Grover**, Baxi Zhong, Howie Choset, “Geometric Mechanics and Gait Design on Cylindrical and Toroidal Shape spaces”, (DSCC 2018)
* **Jaskaran Grover**, Jake Zimmer, Tony Dear, Matt Travers, Howie Choset, Scott Kelly, “Geometric Motion Planning for a Three-Link Swimmer in a Three-Dimensional Low Reynolds-Number Regime”, (ACC 2018)
* **Jaskaran Grover**, Venkat Natarajan “Estimation and Tracking of Knee Angle Trajectory using Inertial Sensors and a Smartphone Application”, (BodyNets 2015)
* **Jaskaran Grover**, Anu Gupta, “Studying Crosstalk Trends for Signal Integrity on Interconnects using Finite Element Modeling”, (COMSOL Conference 2013)

**Work Experience**

**Systems Engineer, Biosignals and Systems Research Group, Intel Labs (07.2014 – 07.2015)**

**Pedestrian position tracking and gait analysis using inertial sensors**

* Developed extended Kalman filtering algorithms for measuring foot trajectory using inertial sensors
* Developed quaternion based orientation estimation algorithm for tracking 3D orientation from IMUs

**Intern, Biosignals and Systems Research Group, Intel Labs (01.2014 – 07.2014)**

**Smart knee motion tracking Solution using wearable bands and mobile phone**

* Created a smart-fabric knee band instrumented with a WSN, IMU and stretch sensors.
* Integrated sensor measurements to track the ‘flexion’ angle of knee joint on a BLE android-tablet.

**Research Experience**

**Graduate Research Assistant, Intelligent Control Lab and Advanced-Agent Robotics Technology Lab**

**Multirobot exploration, path planning and room clearing with mixed integer linear programming**

* Working on exploration of rooms in unknown nonconvex environments to search for friendly/hostile robots
* Developed mixed integer linear program to assign rooms to heterogeneous robots
* Integrated PRM based path planning and barrier certificate controllers for collision avoidance and room clearing

**Adversarial Robustness, Multirobot and Swarm System Identification**

* Derived parameter estimation algorithms for identifying controller and model parameters of multirobot systems and swarms using their observed position information with theoretical guarantees
* Exploring human intent estimation using inverse optimization and system identification

**Multirobot Experiments Arena Development**

* Designed and constructed a multirobot motion experiments arena for benchmarking swarm algorithms on Khepera robots
* Integrated Vicon motion tracking and projector for virtual environments with ROS for feedback control

**Graduate Research Assistant, Biorobotics Lab**

**Geometric gait design for a novel 3D low-Reynolds swimmer with yaw-pitch inputs**

* Derived a dynamics model for a novel three-dimensional swimmer in a viscous regime
* Validated gaits derived from simulations on a physical robot in corn syrup

**Dynamics modeling, design optimization and planning for elastomagnetic swimmers**

* Developed a geometric framework for locomotion control of ferromagnetic swimmers
* Fabricated millimeter scale elastomagnetic swimmers, designed and programmed a Helmholtz coil setup for trajectory tracking using time-varying magnetic fields

**Course Projects**

**Model free control using deep reinforcement learning (01.2018 – 05.2018)**

* Derived robustly stabilizing controllers using off-policy reinforcement learning in TensorFlow
* Benchmarked neural network based controllers against basis-function based controllers on prototype systems

**Fault tolerant control of a quadrotor (08.2016 – 12.2016)**

* Investigated the problem of controlling a quadrotor experiencing propeller failure
* Demonstrated how feedback linearization can be used to control attitude and altitude

**Achievements**

* Recipient of Uber Presidential Fellowship (2019)
* Distinction Divsion, BITS Pilani (2014)
* All India Rank 8 in Graduate Aptitude Test in Engineering, GATE 2014, Instrumentation Engineering (2014)

**Teaching Experience**

Provably Safe Robotics (Fall 2019), Underactuated Robotics (Fall 2018), Robot Kinematics and Dynamics (Fall 2017)

**Mentoring Activities**

Michael Cheng (CMU), Kenneth Shaw (Georgia Tech), Raghavv Goel (IIIT Delhi), Daniel Vedova (CMU), Nalini Jain (CMU)

**Proposal and Research Objectives**

Artificial Intelligence (AI)-systems are increasingly being incorporated in many modern cyberphysical systems (CPSs) such as aircraft and autonomous cars. These CPSs are composed of a number of modules, some of which consist of deep networks for estimation, prediction, and control, in addition to hardware components. As these CPSs are being deployed in the real world, it is becoming critical to ensure that application-specific goals, safety and performance criteria are met with rigorous guarantees. In a dynamic scenario, the environment, the CPS, as well as the requirement of the CPS evolve throughout time. Efficient run-time verification is needed to formally certify safety and performance of the CPS before deployment. Such a scenario is seen in the operation of a manipulator arm around a human in collaborative human-robot assembly tasks as seen in manufacturing. In such a scenario, safe operation of the robot necessitates (1) high-fidelity prediction of human motion, (2) verification of uncertainties of human motion, and finally (3) design and verification of controllers for safe robot control. In the face of these challenges, my aim is to develop algorithms that will foster seamless and safe interactions of robots with humans. Towards that end, I plan to leverage recent progresses in human motion prediction, verification of deep neural networks (DNNs) and control barrier functions for design of safe controllers. I will focus on systems that use DNNs for both prediction and control, requiring verification of (1) uncertainties associated with prediction network and (2) verification of safety constraints required by the outputs of the controller network in the closed loop. A DNN based model for control allows for real-time computational efficiency.

Earlier work in our lab has focused on development of models for human motion prediction using deep networks. I will investigate adaptation algorithms to instantaneously fine-tune these offline-learned networks using human trajectories observed in real-time. This will account for individual differences that exist among different humans as well as time varying behaviors of a particular human. Real-time adaptation, however, also necessitates real-time verification of uncertainty bounds of prediction. With these updated models, I will verify the uncertainty level associated with the prediction model, i.e., what may be the biggest gap between the actual human motion and the predicted human motion from the prediction model. For this, I will employ the NeuralVerification.jl toolbox, consisting of a suite of verification algorithms for soundly verifying DNNs. The toolbox can verify input-output satisfiability problems, i.e., for all possible inputs in an input set, whether the consequent outputs of the neural network belong to a desired output set. I will verify the uncertainty level by computing the maximum output deviation of the prediction from the desired output set.

I will use the human motion prediction model and associated uncertainty levels as inputs to a DNN based avoidance control module to generate real-time safe control for the robot. I will investigate design techniques from non-linear control to transform safety requirements (such as collision avoidance) into equivalent specifications on the outputs of the controller DNN. It is these safety requirements against which the verification algorithm will evaluate and compare the outputs of the controller DNN. The uncertain and time varying nature of the environment resulting from human presence, will pose a computational challenge to the verification process. Changing environment state renders the verification problem dynamic. Re-solving the verification problem in real-time whenever environment changes requires a lot of computation, thus requiring computationally efficient techniques. I will explore how to make this process efficient and scalable for dynamic verification and develop incremental algorithms for verification that ensure fast computation of verification results for both the prediction as well as controller networks. Finally, using the failure modes generated by verification, I will also explore how to repair the networks by leveraging these failure cases.

Ultimately, with this framework, I will focus on integrating ideas from (a) model-based design of safe controllers, (b) reachability-based verification of dynamical systems and (c) verification techniques developed for checking input/output properties of neural networks to analyze safety and performance of closed-loop CPSs, to foster safe and seamless interactions between humans and robots.

**Relevance to Microsoft**

Microsoft Research has Artificial Intelligence and Human Robot Interaction as two of their core research areas. My proposed project fits nicely under both these categories.