

Kshitij Jerath

My overarching research goal is to advance the understanding of complex dynamics observed in large-scale self-organizing systems, and to design bottom-up control algorithms that guide such systems to desired states via minimal intervention. My current work focuses on design and control of robotic swarms, transportation networks, and human-robot teams, with emphasis on the role of a small set of agents in influencing macro-scale system dynamics. In the future I intend to apply the developed tools to diverse networked systems such as social ensembles, system reliability, and neural systems.

EDUCATION

Ph.D., Mechanical Engineering, The Pennsylvania State University 2014

Location: University Park, PA

Advisors: Dr. Sean Brennan and Dr. Asok Ray

Thesis title: *Influential subspaces in self-organizing multi-agent systems*

M.S., Electrical Engineering, The Pennsylvania State University 2014

Location: University Park, PA

Advisors: Dr. Constantino Lagoa

Paper title: *Sensor noise modeling, characterization, and simulation: An Allan variance tutorial*

M.S., Mechanical Engineering, The Pennsylvania State University 2010

Location: University Park, PA

Advisor: Dr. Sean Brennan

Thesis title: *Impact of adaptive cruise control on the formation of self-organized traffic jams on highways*

B.Tech., Mechanical and Automation Engineering, Amity School of Engineering and Technology 2006

Location: New Delhi, India

Advisors: Dr. S B L Garg and Dr. Keshavendra Chaudhary

Thesis title: *Unmanned aerial vehicle for terrain monitoring*

WORK EXPERIENCE

Assistant Professor at University of Massachusetts, Lowell 2018 – Present

- Conducted research on traffic flow and connected autonomous vehicles, swarm robotics, UAVs, and virtual reality interfaces for controlling robotic swarms, human-robot teams
- Taught graduate and undergraduate courses on robotics, control, and system dynamics
- Faculty coordinator for Robotics minor

Assistant Professor at Washington State University 2015 – 2018

- Conducted research on complex systems, swarm robotics, connected autonomous vehicles, UAVs, and virtual reality interfaces for controlling robotic swarms
- Taught undergraduate courses on system dynamics (ME 348), mechatronics (ME 401), control systems (ME 481) and Fundamentals of Engineering Exam review course (ME 466)

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209 Dandeneau Hall, University of Massachusetts, Lowell, MA 01854

- Submitted research and education proposals to NSF, DoE, DARPA, and WSU
- Faculty advisor for WSU Aerospace club

Post-doctoral scholar at The Pennsylvania State University 2014 – 2015

- Incorporated sensor systems into vehicle conceptual design and mission analysis for unmanned aerial systems as a post-doctoral scholar in the Department of Aerospace Engineering

Instructor at The Pennsylvania State University 2013 – 2015

- Primary instructor for senior-level course on Aerospace Control Systems (AERSP 460) and junior-level course on Vibration of Mechanical Systems (ME 370) in Fall 2013
- Held classes and office hours, assigned homework, conducted exams and assessed student performance

Graduate Teaching Assistant at The Pennsylvania State University 2011 – 2013

- Held recitation classes, and graded exams and homework assignments for:
 - Graduate-level course on Digital Signal Processing (ACS 513)
 - Senior-level course on Modeling of Dynamic Systems (ME 450)
 - Junior-level course on Vibration of Mechanical Systems (ME 370)

Graduate Research Assistant at The Pennsylvania State University 2007 – 2011

- Developed theory and performed simulations to study effect of intelligent vehicles on traffic flow
- Implemented and experimentally validated real-time vehicle tracking algorithm with low-cost sensors
- Performed data analysis and generated failure models for transit buses and its components
- Published papers at conferences and in peer-reviewed journals

Research Associate (Intellectual Property) at Evalueserve 2006 – 2007

- Drafted patents for inventions in the fields of navigation/mechanical devices, and web utilities
- Performed invalidation searches for utility and design patents
- Analyzed patent landscape of aircraft health monitoring systems for leading aircraft manufacturer

GRANTS AND CONTRACTS

Army Research Lab: Trust-NEARCHAT: Trust Network Emergence Amongst Resource-Constrained Human-Agent Teams \$1.5 million 2021 – 2024

- **PI: Kshitij Jerath;** co-PIs: Paul Robinette, Reza Ahmadzadeh
- Awarded through Army Research Lab's STRONG (Strengthening Teamwork for Robust Operations in Novel Groups) program
- Examine impact of resource constraints applied to individual learning agents on the macroscopic level emergence of trust networks in teams

Army Research Lab: CHATS: Computational HAT model of status sensitivity to facilitate team trust and performance under suboptimal conditions \$177,665* 2021 – 2024

- **PI: Kshitij Jerath;** co-PIs: Paul Robinette, Reza Ahmadzadeh
- *Total award amount: \$1.5 million. Sub-award through University of Delaware
- Create and implement robots to assist human teammates in an escape room scenario.

Army Research Lab: Individualized Adaptations to Calibrate Multi-Human Multi-Agent Team Trust	\$99,507	2021 – 2022
<ul style="list-style-type: none"> • PI: Paul Robinette; co-PIs: Kshitij Jerath, Reza Ahmadzadeh, Thanuka Wickramarathne • Enabling intelligent agents to reason about trust decisions made by human teammates and apply an appropriate future policy of actions to symbiotically improve overall team processes. 		
NSF: MRI: Development of a Calibration System for Stereophotogrammetry to Enable Large-Scale Measurement and Monitoring	\$455,096	2020 – 2022
<ul style="list-style-type: none"> • PI: Alessandro Sabato; co-PIs: Christopher Niezrecki, Yan, Luo, Kshitij Jerath • Awarded through Major Research Instrumentation (MRI) program at NSF to develop multi-sensor system for real-time calibration of stereophotogrammetry and remotely paired digital cameras 		
Army Research Lab: Emergence of Trust Clusters in Human-Agent Teams Operating under Resource Constraints	\$99,861	2020 – 2021
<ul style="list-style-type: none"> • PI: Kshitij Jerath; co-PIs: Paul Robinette, Reza Ahmadzadeh • Awarded through Army Research Lab's STRONG (Strengthening Teamwork for Robust Operations in Novel Groups) program • Assess subsequent impacts on team performance and cohesion in soldier-robot teams conducting search and rescue operations 		
DEVCOM Soldier Center: DECISIVE: Development and Execution of Comprehensive and Integrated Subterranean Intelligent Vehicle Evaluations	\$1,130,930	2020 – 2021
<ul style="list-style-type: none"> • PI: Holly Yanco; co-PIs: Reza Ahmadzadeh, Kshitij Jerath, Adam Norton, Paul Robinette, Jay Weitzen, Thanuka Wickramarathne • Design and evaluation of test methods for obstacle avoidance and navigation algorithms for small Unmanned Aerial Systems 		
NSF: CPS: Medium: Collaborative Research: Automated Discovery of Data Validity for Safety-Critical Feedback Control in a Population of Connected Vehicles	\$501,150*	2019 – 2022
<ul style="list-style-type: none"> • PI: Kshitij Jerath; co-PI: Cindy Chen • *Total award amount: <u>\$1.2 million</u>. Awarded through cross-disciplinary Cyber Physical Systems (CPS) program at National Science Foundation (NSF). <p>Identify spatiotemporal scales over which information remains relevant in the context of friction measurements using connected vehicles on freeways</p>		
NSF: Scale-dependent observability of emergent dynamics: Application to Traffic Flow with Connected Vehicles	\$259,749	2017 – 2021
<ul style="list-style-type: none"> • PI: Kshitij Jerath • Awarded through CMMI Dynamics, Control and System Diagnostics (DCSD) program at NSF • Assess optimal scale to observe and predict complex traffic flow dynamics using connected vehicles 		

RESEARCH AND ENGINEERING EXPERIENCE

Identifying influential subspaces of agents in self-organizing multi-agent systems	2013 – Present
<ul style="list-style-type: none"> • Developed framework for evaluating agent influence in networked multi-agent systems • Identified influential subspaces on highways where connected vehicles can impact self-organized jams • Performed observability analysis for reduced order models of complex nonlinear traffic dynamics 	
Emergence of trust in multi-agent teams	2019 – Present
<ul style="list-style-type: none"> • Implemented multi-agent reinforcement learning (MARL) in simulated robot navigation tasks 	
Modeling and control of robotic swarms	2015 – Present
<ul style="list-style-type: none"> • Generated multi-scale models and state estimators for robotic swarms • Created efficient controllers and exploration-coverage algorithms for robotic swarms • Developed human gesture-based virtual reality control of robotic swarms using Unreal game engine 	
Sensor-driven conceptual design for small unmanned aerial system (UAS)	2014 – 2018
<ul style="list-style-type: none"> • Developed simulation framework for photorealistic simulations of UAS waypoint navigation missions • Performed Monte Carlo simulations of navigation missions with on-board lidars and cameras 	
Studying the effects of intelligent and connected vehicles on traffic flow dynamics	2008 – Present
<ul style="list-style-type: none"> • Generated and analyzed stochastic models of traffic jam dynamics • Analyzed the effect of variations in parametric driver models on the formation of traffic jams • Performed microscopic simulations of traffic flow using statistical mechanics-inspired models 	
Human detection in complex construction environments	2012
<ul style="list-style-type: none"> • Conducted proof-of-concept study for major construction equipment manufacturer to detect humans at construction sites using LIDAR 	
GPS-free terrain-based vehicle tracking	2009 – 2011
<ul style="list-style-type: none"> • Developed noise models for simulating low-cost sensors • Implemented real-time vehicle tracking with simulated low-cost sensors using Sigma Point Kalman filters in absence of GPS • Implemented vehicle tracking on large road networks using multiple model estimation schemes 	
Reliability analysis of in-service transit buses	2007 – 2009
<ul style="list-style-type: none"> • Analyzed failure rate data from transit buses and Larson Transportation Institute bus testing program using regression and Hidden Markov models • Generated performance comparison scheme for bus models and agencies 	
Design of unmanned aerial vehicle	2006
<ul style="list-style-type: none"> • Designed, built and flew an R/C Unmanned Aerial Vehicle (UAV) • Initiated project idea, formed and managed a group of 10 persons for 5 months • Performed feasibility studies for various design specifications 	

Testing of Hydraulic Control Unit on Airbus A320

2005

- Observed assembly, disassembly and maintenance procedures for jet engines (IAE V2500 and Pratt and Whitney JT8D) at the Jet Engine Overhaul Complex (JEOC), New Delhi, India
- Helped develop in-house testing setup for the Hydraulic Control Unit (HCU) of the Nose wheel steering system on the Airbus A320 at the Aircraft Accessory Overhaul Shop, Indian Airlines Ltd., New Delhi, India

Anti-Lock Braking System (ABS)

2004

- Designed and built an anti-lock braking system for hydraulic brakes of a compact car using 3-way solenoid valve and induction proximity sensor

PUBLICATIONS

^*IEEE Trans. on Intelligent Transportation Systems* is the top-ranked journal in the field of transportation as per Google Scholar Metrics. It has an Impact Factor of 6.319.

^*Measurement* has an Impact Factor of 3.364.

^*IEEE Control System Letters* has an Impact Factor of 1.064.

Journal Publications

1. T. Kim*, and **K. Jerath**; *Congestion-aware Cooperative Adaptive Cruise Control and Mitigation of Self-Organized Traffic Jams*, IEEE Transactions on Intelligent Transportation Systems, *In press*.
2. H. Haeri*, C. Beal, and **K. Jerath**, *Near-optimal Moving Average Estimation at Characteristic Timescales: An Allan Variance Approach*, IEEE Control Systems Letters, vol. 5, no. 5, pp. 1531-1536, 2020
3. H. Haeri*, **K. Jerath**, and J. Leachman, *Thermodynamics-inspired Macroscopic States of Bounded Swarms*, ASME Letters in Dynamic Systems and Control, vol. 1, pp 011-015, 2020
4. **K. Jerath**, S. Brennan, and C. Lagoa, *Bridging the gap between sensor noise modeling and sensor characterization*, Measurement, vol. 116, pp 350-366, 2018
5. **K. Jerath**, A. Ray, S. Brennan, and V. V. Gayah, *Dynamic prediction of vehicle cluster distribution: A statistical mechanics-inspired approach*, IEEE Transactions on Intelligent Transportation Systems, vol. 16, no. 5, 2015
6. **K. Jerath** and S. Brennan; *Analytical Prediction of Self-Organized Traffic Jams as a Function of Increasing ACC Penetration*, IEEE Transactions on Intelligent Transportation Systems, vol. 13, no. 4, 2012
7. J. Yutko, **K. Jerath**, and S. Brennan; *A Failure Rate Analysis of Complex Vehicles*, International Journal of Heavy Vehicles and Systems, vol. 17, no. 1, 2010

Submitted Manuscripts

8. **K. Jerath**, V. V. Gayah, and S. Brennan; *Event Horizons and Influential Subspaces of Connected Vehicles*, submitted to Transportmetrica A

Publications in Refereed Conference Proceedings

9. S. S. P. Maddipatla, H. Haeri*, **K. Jerath**, S. Brennan; *Fast Allan Variance (FAVAR) and Dynamic Fast Allan Variance (D-FAVAR) Algorithms for both Regularly and Irregularly Sampled Data*, to appear in Proceedings of the Modeling, Estimation, and Control Conference (MECC) 2021, Austin, TX, USA
10. H. Haeri*, R. Ahmadzadeh, and **K. Jerath**; *Reward-Sharing Relational Networks in Multi-Agent Reinforcement Learning as a Framework for Emergent Behavior*, Adaptive and Learning Agents Workshop 2021, London (virtual)

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- H. Haeri*, C. Beal, and **K. Jerath**; *Near-optimal Moving Average Estimation at Characteristic Timescales: An Allan Variance Approach*, Accepted for presentation at the American Control Conference, New Orleans, LA, USA, 2021
- 11. L. Gao, S. Maddipatla, C. Beal, **K. Jerath**, C. Chen, L. Sinanaj, H. Haeri, and S. Brennan; *A Micro-simulation Framework for Studying CAVs Behavior and Control Utilizing a Traffic Simulator, Chassis Simulation, and a Shared Roadway Friction Database*, American Control Conference, New Orleans, LA, USA, 2021
- 12. Z. Yang*, H. Haeri*, and **K. Jerath**, *Renormalization Group Approach to Cellular Automata-based Multi-scale Modeling of Traffic Flow*, Unifying Themes in Complex Systems X: Proceedings of the Tenth International Conference on Complex Systems (Springer Proceedings in Complexity), Nashua, NH, 2020
- 13. Z. Yang* and **K. Jerath**, *Observability Variation in Emergent Dynamics: A Study using Krylov Subspace-based Model Order Reduction*, American Control Conference 2020, Denver, CO, USA
- H. Haeri*, **K. Jerath**, and J. Leachman; *Thermodynamics-inspired Modeling of Macroscopic Swarm States*, Dynamic Systems and Controls Conference, Salt Lake City, UT, USA, 2019
- 14. Z. Yang* and **K. Jerath**, *Examining the Observability of Emergent Behavior as a Function of Reduced Model Order*, American Control Conference 2018, Milwaukee, WI, USA
- 15. M. Scott* and **K. Jerath**, *Multi-robot Exploration and Coverage: Entropy-based Adaptive Maps with Adjacency Control Laws*, American Control Conference 2018, Milwaukee, WI, USA
- 16. M. Scott* and **K. Jerath**; *Mission Performance Evaluation of Low-speed Small Unmanned Aerial Systems using Virtual Range and Stereo Camera Sensors*, AIAA Unmanned Systems Conference, 2018, Kissimmee, FL, USA
- 17. T. Kim*, and **K. Jerath**; *Mitigation of self-organized traffic jams using cooperative adaptive cruise control*, 2016 International Conference on Connected Vehicles and Expo (ICCVE), 2016, Seattle, WA, USA
- 18. **K. Jerath**, and J. Langelaan; *Simulation Framework for UAS Conceptual Design*, AIAA Modeling and Simulation Technologies Conference, 2016, San Diego, CA, USA
- 19. **K. Jerath** and S. Brennan; *Identification of locally influential agents in self-organizing multi-agent systems*, American Control Conference 2015, Chicago, IL, USA
- 20. **K. Jerath**, V. V. Gayah, and S. Brennan; *Influential Subspaces of Connected Vehicles in Highway Traffic*, Symposium Celebrating 50 Years of Traffic Flow Theory, TRB Committee on Traffic Flow Theory and Characteristic, 2014, Portland, OR, USA
- 21. **K. Jerath**, A. Ray, S. Brennan, and V. Gayah; *Statistical Mechanics-inspired Framework for Studying the Effects of Mixed Traffic Flows on Highways*, Proc. of American Control Conference, 2014, Portland, OR, USA
- 22. **K. Jerath** and S. Brennan; *GPS-Free Terrain-based Vehicle Tracking on Road Networks*, Proceedings of American Control Conference, 2012, Montreal, Canada
- 23. **K. Jerath** and S. Brennan; *GPS-Free Terrain-based Vehicle Tracking Performance as a function of Inertial Sensor Noise Characteristics*, Proc. of Dynamic Systems and Control Conference, 2011, Arlington, VA, USA
- 24. **K. Jerath** and S. Brennan; *Adaptive Cruise Control: Towards higher traffic flows, at the cost of increased susceptibility to congestion*, Proceedings of AVEC10, 2010, Loughborough, UK
- 25. R. Deshpande, D. Johar, A. Kasyap, C. Feng, **K. Jerath**, and Z. Li; *Intellectual Property Monetization by R&D Organizations in India and China*, Proceedings of the International Symposium on the Management of Technology, 2007, Hangzhou, PRC

In preparation

- 26. Z. Yang* and **K. Jerath**, *Statistical mechanics-inspired traffic flow modeling across multiple spatial scales: A renormalization group theoretic approach*, for submission to Physical Review E
- 27. S. Barclay*, H. Haeri*, and **K. Jerath**; *Human-guided Autonomous Swarms in Virtual-Reality Environments using Impedance Control*, for re-submission to Robotics and Automation Letters

28. M. Scott*, and **K. Jerath**; *Sensor-based Conceptual Design of Small UASs in Photorealistic Environments*, for submission to Journal of Aircraft

Technical Reports and Other Publications

29. C. Pezeshki and **K. Jerath**, *Canonical Knowledge Structures and Complexity in the Design of Artificial Intelligence*, International Conference on Complex Systems, Nashua, NH, 2020
30. **K. Jerath**; *Influential subspaces in self-organizing multi-agent systems*, Ph.D. dissertation, Department of Mechanical and Nuclear Engineering, The Pennsylvania State University, 2014
31. S. Brennan, P. Vemulapalli, **K. Jerath**, M. Robinson, M. Guo, *Human detection to increase safety in complex construction environments*, Technical report, Penn State/Volvo Construction Equipment, 2012
32. **K. Jerath**; *Cooperative Intelligent Vehicles: Are we there yet?*, Award-winning entry to the ITSA Student Essay Competition, 2012
33. **K. Jerath**; *Impact of Adaptive Cruise Control on the Formation of Self-Organized Traffic Jams on Highways*, M.S. Thesis, Department of Mechanical and Nuclear Engineering, The Pennsylvania State University, 2010
34. S. Brennan, **K. Jerath**, D. Klinikowski, S. Muthiah, and J. Yutko, *Study of the relationship between results of the Bus Testing Program and in-service performance of buses*, Technical Report, The Pennsylvania State University, 2008

TEACHING EXPERIENCE

University of Massachusetts Lowell 2018 – Present

- **MECH 3220**: Control of Mechanical Systems (redesigned course for project-based learning)
- **MECH 4510**: Dynamic Systems Analysis
- **MECH 5300**: Autonomous Robotic Systems (developed graduate course and projects)
- **MECH 5540**: Dynamic Systems and Control

Washington State University 2015 – 2018

- **ME 348**: System Dynamics
- **ME 401**: Mechatronics
- **ME 481**: Control systems (introduced robotics-based projects to enhance learning outcomes)

Penn State University 2013 – 2014

- **AERSP 460**: Aerospace Control Systems
- **ME 370**: Vibrations of Mechanical Systems

HONORS

- Awarded **Best Presentation in Session** at the American Control Conference, 2014
- Received the **Kulakowski Travel Award** by the Department of Mechanical and Nuclear Engineering at The Pennsylvania State University, 2014
- **Media coverage**: Research mentioned in **Society of Industrial and Applied Mathematics News** – “*Smells like a traffic jam*”, November 2013
- Awarded **Graduate Teaching Fellowship** by Department of Mechanical and Nuclear Engineering at The Pennsylvania State University, 2013
- Awarded **Best Presentation in Session** at the American Control Conference, 2012

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- Awarded 2nd place in Student Essay Competition organized by **Intelligent Transportation Society of America**, 2012 for essay titled “*Cooperative intelligent vehicles: are we there yet?*”
- Awarded **Scholar’s Gold Medal** in 2000 for sustained academic excellence over a period of six years in high school.
- Awarded **National Merit-cum-Means Scholarship** under National Scholarship Scheme of the Govt. of India for ‘outstanding performance in the Board’s Secondary School Examination 2000’.
- Awarded **Certificate of Merit** by CBSE for being among the top 0.1 % of successful candidates in All India Secondary School Examination, 2000, in science.

PROFESSIONAL AND OTHER ACTIVITIES

- **Member of**
 - ASME Automotive and Transportation Systems (ATS) Technical Committee
 - IEEE Intelligent Transportation Systems Society (ITSS)
 - IEEE Systems, Man, and Cybernetics Society (SMC)
 - American Institute of Aeronautics and Astronautics (AIAA)
 - American Society for Engineering Education (ASEE)
- **Reviewer for**
 - IEEE Transactions on Intelligent Transportation Systems
 - IEEE Intelligent Transportation Systems Magazine
 - IEEE Transactions on Vehicular Technology
 - IEEE Transactions on Automatic Control
 - Journal of Network and Computer Applications
 - Transportation Research Record
 - American Control Conference
 - Dynamic Systems and Control Conference
 - International Conference on Complex Systems
- **Reviewed proposals** as part of NSF review panel, and for Canada Foundation for Innovation (CFI)
- **Attended Conferences and Workshops:**
 - American Control Conference (2012, 2014, 2015, 2017, 2018, 2020)
 - Dynamic Systems and Controls Conference (2011, 2019)
 - International Conference on Complex Systems (2018, 2020)
 - Annual Meeting of the Transportation Research Board, Washington D.C., Jan 11-13, 2019
 - Collective Intelligence Conference, New York, NY (2017)
 - International Conference on Connected Vehicles and Expo, Seattle, WA (2016)
 - AIAA Modeling and Simulation Conference, San Diego, CA (2016)
 - TRB Symposium Celebrating 50 Years of Traffic Flow Theory, Portland, OR (2014)
 - NSF Cyber Physical Systems PI Meeting, Washington D.C. – Nov 21-22, 2019
 - 3rd Robotics Roadmapping Workshop, Lowell, MA – Nov 15-16, 2019
 - Presenting Data and Information with Edward Tufte, Cambridge, MA, June 3, 2019
 - NSF Grants Conference, Alexandria, VA (2016)
 - WSU Office of Research Advancement and Partnership Grant writing course (2016)
 - Active Learning Workshop by National Effective Teaching Institute (NETI) at Pullman, WA (2016)
- **Program Chair** for International Conference on Complex Systems (2020) at Nashua, NH
- **Organized invited sessions** at various conferences:

- *Advanced Driver Assist Systems* at American Control Conference 2021 in New Orleans, LA
- *Connected vehicle systems* at Dynamic Systems and Controls Conference 2020 in Pittsburgh, PA
- *Influence in multi-agent systems* at the American Control Conference (ACC) 2015 in Chicago, IL
- *Systems, Control and Communication* at College of Engineering Research Symposium 2014 at Penn State University, State College, PA
- **Chaired/co-chaired regular sessions** at various conferences:
 - *Observers for nonlinear systems* at American Control Conference 2020 in Denver, CO
 - *Large-scale systems* at American Control Conference 2018 in Milwaukee, WI
- **University and department committees at UMass Lowell:** Robotics Faculty search committee (chair (2019), member (2018)), Robotics Strategic Planning Working Group (Team Lead, 2019-20), Faculty Coordinator for Robotics Minor (2019-20)
- **University and department committees at WSU:** Member of UAS drone safety committee (WSU Department of Environmental and Health Safety, 2016-17), Undergraduate Studies committee (MME department, 2016-17), and Website redesign committee (MME department, 2015-16)
- Advised WSU Aerospace club for the Intercollegiate Rocket Engineering Competition (IREC): 2015-17
- Member, Penn State Robotics Club and Intelligent Ground Vehicle Competition (IGVC) Team: 2007-2009
- Coordinator of Student Activities, SAE Student Chapter at Amity School of Engineering and Technology: 2005-2006

COMPUTER SKILLS

- Languages: C, C++, Python, Java, HTML and CSS, R, SQL
- Tools handled: Robot Operating System (ROS), Blender, Modular Open Robot Simulation Engine (MORSE), Matlab, Simulink, Scilab, RePast Symphony, QuaRC, AutoCAD, MiniTab
- Proficient in MS Word, LaTeX, MS PowerPoint, and MS Excel