Kaustubh Joshi

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Education

Ph.D. (Doctor of Philosophy), Mechanical Engineering Jan 2022 - Present
University of Maryland, College Park
Advisor: Prof. Nikhil Chopra, Department of Mechanical Engineering
Research Areas: *State Estimation & Control; Robot Navigation; Field Robotics; Decision-Making for Robotics*

B. Tech (Bachelor of Technology), Ocean Engineering and Naval Architecture Jul 2016 - Jul 2020
Indian Institute of Technology (IIT) Madras
Minor Stream: Automation
Thesis: Seafloor Mapping & Localization For A Multi-Robot System Using Route Optimization Algorithms [pdf]
Advisor: Prof. T. Asokan, Department of Engineering Design, IIT Madras

Professional Experience

Graduate Research Assistant, University of Maryland College Park	Jan 2022 - present
Graduate Teaching Assistant, University of Maryland College Park	Fall 2022, Fall 2024
Research Associate, Indian Institute of Science (IISc), *Bangalore, India*	Aug 2020 - Dec 2021
Research Intern, Tata Consultancy Services (TCS) Research Labs, *Pune, India*	May 2019 - July 2019
In-Plant Trainee, Cochin Shipyard Ltd., *Kochi, India*	June 2018 - July 2018

Selected Awards and Honors

· Selected for the Future Faculty Fellowship at University of Maryland's Clark School of Engineering, recognizing academic excellence and potential as an educator and researcher, along with a travel grant of **USD $2000**
· Solely selected as representative for Indian students in USA at the NSF[1] to present research to the First Lady Dr. Jill Biden, Hon'ble Indian PM Narendra Modi and NSF Director Dr. Sethuraman Panchanathan during PM Modi's official state visit to USA (2023) [link 1] [link 2] [link 3]
· **Best Paper Award** for "Best Control Framework for Autonomous Navigation and Control" at IROS 2024 Workshop on Autonomous Robotic Systems in Aquaculture: Research Challenges and Industry Needs
· Nominated for the Subramanian Rajalakshmi Indira Endowment prize for the **Best Interdisciplinary Project** in the graduating batch of 1000 students of IIT Madras
· Awarded a travel grant of **INR 50,000** by IIT Madras for presenting a paper at ICOE[2] 2019
· Awarded scholarship of **INR 25,000** by Government of Maharashtra for academic excellence in SSC[3] exam
· Awarded as Most Promising Player in All India Inter Collegiate Jimmy George Volleyball Gold Cup 2018

Skills

Programming Languages	Python, MATLAB, C & C++; Familiar with R, Fortran, SQL
Tools/Technologies	Git, Docker, LaTeX, PixHawk, MAVLink, Arduino
Robot Platforms	Turtlebot 2, Turtlebot 3, BlueROV2, UR3e, Crazyflie
Robot Software & Simulation	ROS, ROS 2, Gazebo, WeBots, NVIDIA Issac Sim
Vision/AR/VR Systems	Intel Realsense, Orbbec Astra, DVX Event Camera, Quest 3, Magic Leap
3D Design & Printing	Experienced in AutoCAD, Solidworks and 3D printing on Ultimaker, Raise 3D
Creative Media	Adobe Photoshop, Premiere Pro, Illustrator, After Effects, Autodesk Maya

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[1] National Science Foundation [2] 5th International Conference on Ocean Engineering [3] Secondary School Certificate

PUBLICATIONS & PATENTS

Peer-Reviewed Conferences:

[C1] **Joshi, K.**, Liu, T., Chopra, N. "Cascade IPG for Underwater Robot Pose Estimation", IEEE International Conference on Robotics and Automation **(ICRA 2025)** *(accepted)*

[C2] Lin, X., Karapetyan, N., **Joshi, K.**, Liu, T., Chopra, N., Yu, M., Tokekar, P. and Aloimonos, Y., 2024, May. UIVNav: Underwater information-driven vision-based navigation via imitation learning. IEEE International Conference on Robotics and Automation **(ICRA 2024)** [manuscript][link]

[C3] **Joshi K.**, Saha N. (2021) "Estimation of Ship Heave and Pitch Under Wave Loads Using Kalman Filtering". In: Proceedings of the Fifth International Conference in Ocean Engineering (ICOE 2019). Lecture Notes in Civil Engineering, vol 106. Springer, Singapore [manuscript] [link]

Journals:

[J1] **Joshi, K.**, Roy Chowdhury, A. (2022). "Bio-Inspired Vision and Gesture-Based Robot-Robot Interaction for Human-Cooperative Package Delivery". **Frontiers in Robotics and AI**, [link] [video] *(Editor's Pick and Most Viewed Article of July 2022)*

Patents:

[P1] **Joshi, K.**, Liu, T., Chopra, N. "Cascaded Observer For Pose Estimation", **U.S. Patent** *(pending approval)*

Workshop/Lightly Reviewed Papers:

[L1] **Joshi, K.**, Liu, T., Williams, A., Gray, M., Lin, X., Chopra, N. (2024). "3D Water Quality Mapping using Invariant Extended Kalman Filtering for Underwater Robot Localization", IEEE/RSJ International Conference on Intelligent Robots and Systems **(IROS 2024)**: Workshop on Autonomous Robotic Systems in Aquaculture: Research Challenges and Industry Needs [link to paper] [link to workshop] [poster] *(Best Paper Award for Best Control Framework for Autonomous Navigation & Control, 300USD Prize)*

Under Review:

[U1] Chen W., Wang C., **Joshi K.**, Chen Y., Kumar S., Pattillo A., Yu M., Chopra N., Tao Y. "Ship Maneuvering and Dynamic Navigation for Precision Aquaculture based on Combined Nomoto-Dubins Model". International Journal of Naval Architecture and Ocean Engineering

POSTERS

[P1] Gray, M., Yu M., Xu M., Pattillo A., Tao Y., **Joshi K.**, Chopra N., Webster D., Parker M., Liu C., Hudson B., Jin Y., Wang C., Aloimonos Y., Williams A., Magnusson G.."Smart, Sustainable, Shellfish Aquaculture Management: Advancing Technological Development Of Oyster Aquaculture In The USA" **Aquaculture Europe 2024**

[P2] **Joshi, K.**, Liu, T., Chopra, N. "Localization, Navigation and Autonomous Control of ROV" Maryland Robotics Center (MRC) Research Symposium 2024

[P3] Rao P.*, **Joshi K.***, Roy Chowdhury A. (2021) "Deep Audio-Visual Learning based Action Prediction in a Human-Robot Coordinated Task". 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems **(IROS 2021)**, Prague, Czech Republic (online) [abstract] [poster]

RESEARCH HIGHLIGHTS

Graduate Research Assistant, **University of Maryland College Park** *Jan 2022 - Present*
Advisor: *Dr. Nikhil Chopra, Semi-Autonomous Systems Lab*

1. **Robot Pose Estimation and Control**
· Devised and implemented novel nonlinear observers based on iteratively preconditioned gradient descent (IPG) for precise 3D pose estimation of underwater robots using DVL and IMU data, during vision occlusions

- Developed these observers to rely solely on sensor data without requiring knowledge of the robot's dynamic model, enabling flexibility and adaptability to diverse underwater conditions and different robots & systems.
- Demonstrated that the proposed observers outperform state-of-the-art methods, such as Invariant Extended Kalman Filters (InEKF), through rigorous experimental validation in Chesapeake Bay, MD. [C1]
- Introduced a novel system integrating InEKF for precise underwater robot localization, significantly advancing 3D mapping of water quality parameters in aquaculture environments. [L1]
- Currently working on interfacing a vision modality in the existing pipeline to use an attention-based differentiable filter for pose estimation, to ensure robust estimate in cases of sensor outages.

2. **Imitation Learning-based Robot Navigation**
- Collaborated on designing a novel imitation learning-based underwater navigation system (UIVNav) that utilizes an intermediate representation for obstacle avoidance and efficient information gathering over objects of interest (OOI) without requiring localization or retraining for new environments.
- Successfully demonstrated the feasibility of UIVNav through simulations and real-world experiments using a BlueROV2, achieving 36% more OOI coverage compared to state-of-the-art complete coverage methods. [C2]
- Currently integrating the imitation learning framework with temporal logic and a Vision Language Model (VLM) to enable underwater robots to interpret high-level mission objectives for autonomous navigation.

3. **Autonomous Surface Vessel (ASV) for 3D Mapping & Reconstruction**
- Actively worked on designing and developing the mechanical, electrical and computational components of an in-house ASV, mounted with multibeam SONAR, cameras and GPS sensors, for 3D coastal mapping
- Processed vision data through 3D reconstruction methods of ColMap, ACEZero, MASt3R, ODM
- Currently working on a vision transformer for semantic segmentation of front facing SONAR data

Research Associate, **Indian Institute of Science (IISc)**   *Sept 2020 - Dec 2021*
Guide: <u>*Prof. Abhra Roy Chowdhury*</u>, <u>*Robotics Innovations Lab*</u>

1. **Vision-based Gestural Interaction for a Human Cooperative Multi-Robot System:**
- Implemented a object detection and tracking methodology using a RGB-D camera for bioinspired robot-robot interaction eliminating the need for communication over networks [J1]
- Executed a human cooperative package delivery task in an industrial testbed using Turtlebot 2 & Turtlebot 3

2. **Audio-Visual Navigation for Collaborative Task Execution:**
- Devised a transfer learning methodology for robot navigation towards static and dynamic objects
- Formulated a real-time heuristic approach to plan a path towards a destination combining signals from 4-channel microphone array and a RGB-D camera [P3]

Undergraduate Student, **Indian Institute of Technology (IIT), Madras**

Multi-Robot SLAM for Underwater Robots   *July 2019 - June 2020*
Guide: <u>*Prof. T. Asokan*</u>, *Robotics Lab, Department of Engineering Design*

- Simulated a decentralized multi-robot system to map the seafloor using an **Active 3D SLAM** framework
- Used **graph-based EKF-SLAM** in a simulated environment for generating topography of the seafloor
- Implemented the **DARP** (Divide Areas Based on Robots Initial Positions) algorithm for the multi-robot system and planned each robot's route by solving the **TSP**[4] using **ACO**[5]

Kalman Filtering for Ship Stability
Guide: <u>*Prof. Nilanjan Saha*</u>, *Department of Ocean Engineering*   *Sept 2018 - Feb 2020*

1. **Kalman Filtering for Ship Stability**:
- Estimated the ship attitude and damping coefficients under linear wave loading using Kalman Filters
- Formulated dynamic longitudinal loads for ship motion calculations using strip theory & Airy wave theory
- Estimated the unknown parameters of sectional wave exciting force & hydro-mechanic force using **Extended Kalman Filter**(EKF) and mitigated the singularities by applying an **Ensemble Kalman Filter**(EnKF)

2. **Simulation of stopped diffusion using Unscented Kalman Filters**:
- Applied the Unscented Kalman Filter on the stopped diffusion problem to estimate the exit time of particles
- Simulated 100 particles in Brownian motion and formulated their SDE[6] using the **Feynman-Kac formula**

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[4] Travelling Salesman Problem   [5] Ant Colony Optimization   [6] Stochastic Differential Equations

Underwater Robot Hull Design & Communication
Guide: <u>Prof. R. Vijayakumar</u>, Department of Ocean Engineering   *Oct 2017 - Feb 2018*

· Designed hull & analyzed dynamics of neutrally-buoyant underwater robot using NACA[7] profile in Rhinoceros
· Used Arduino Mega microcontroller and programmed it for a camera and 3 thrusters with varying speeds
· Achieved a wireless communication till 50cm water depth and 10m ground distance using an Xbee radio module

INDUSTRY PROJECTS

Research Intern, **TCS Research Labs**   *May - July 2019*
Manufacturing IoT Lab, Tata Consultancy Services, India

1. **Wearable Pose Estimation using an Inertial Measurement Unit**
   · Developed a 6-DoF pose estimation methodology using inertial sensors on a Raspberry Pi 3B+ for real-time position and orientation tracking on embedded wearable devices for **gesture tracking** in manufacturing
   · Incorporated and efficiently tuned a **QEKF**[8] to get rid of Gimbal lock and obtain finer estimates

2. **UWB-based Indoor Real-Time Location System:**
   · Created a real-time location system (RTLS) on a client-server architecture using **ultra-wideband (UWB)** communication, for item tracking in smart warehouses
   · Successfully implemented an algorithm on MySQL to convert coordinates to precise GPS coordinates on a QGIS [9] map using fundamental coordinate transformations, **reducing computation time by 30%**

TEACHING

ENME480: Introduction to Robotics, University of Maryland   *Fall 2022, Fall 2024*
Graduate Teaching Assistant

· Designed and organized lab sections of the first course in the robotics minor at UMD, for introduction to Python, ROS/ROS2, Gazebo and hands-on experiments with UR3e robot arm
· Developed a comprehensive ROS & Gazebo tutorial, and curated weekly studio sessions and assignments
· Transitioned entire lab course material consisting of ROS packages and instructional material to GitHub [`link`]

INVITED TALKS

· S3AM Webinar: Water Quality Monitoring & Sensing for Aquaculture with Emerging Technologies (2023)[`link`]
· NSF - Official State Visit of Hon'ble Indian PM Modi to USA (2023) "Robotics in US Aquaculture Industry & Potential Applications in India"

MEDIA COVERAGE

· "Modi Briefed on UMD-led Aquaculture Research" Maryland Robotics Center [`link`]
· "Pune Researcher's Deep Sea Pearl-Finding Robot Impresses PM Modi during US Visit" Punekar News [`link`]
· "Come to India, Modi Tells US Teachers", Rediff.com [`link`]
· "Eyes on the Prize Catch" Chesapeake Quarterly, A Magazine by Maryland Sea Grant by Ashley Goetz [`link`]
· "Now, robots that can navigate using visual cues, deliver packages; researchers used 'waggle dance' bees use" **The Times of India** [`link`]
· "When bee dance inspires robot design" **Deccan Herald** [`link`]
· "Inspired by honeybees, scientists teach robots to communicate with 'waggle dance'" **Indian Express** [`link`]
· "Bees' 'waggle dance' may revolutionize how robots talk to each other in disaster zones" Frontiers [`link`]
· "Dancing bees inspire alternative communication system for robots" New Atlas [`link`]
· "Bee waggle dance inspires new method of robot communication" Earth.com [`link`]

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[7] Airfoil shapes developed by the National Advisory Committee for Aeronautics (NACA)   [8] Quaternion Extended Kalman Filter
[9] A cross-platform, open-source geographic information system (GIS) software for analysing and editing geospatial data

Volunteer and Services

· Reviewer: **ICRA** 2023, 2024, 2025 **RA-L** 2024, **Humanoids** 2024, **IFAC-CAMS** 2024
· **Life Is A Ball:** Worked with the NGO to provide resources and training in sports for underprivileged kids
· **Honourpoint:** Produced videos to garner exposure about exploits of the Indian Army and martyred soldiers

Mentorship

· Yash Pandit (High School Student - Poolesville High School, MD)
  – Working on custom object detection using YOLOv8 for localizing an underwater robot in indoor settings
  – Presented posters in county science fairs and secured second place in Montgomery County Science Expo
· Suvan Sudan (BS MechE - UC Davis, Summer Research Intern at UMD)
  – Worked on developing a hybrid Soft Robotic Gripper for an underwater robot aimed to collect oyster samples from the seabed
· Senior Capstone Design Project (Dept. of Mechanical Engineering - UMD)
  – Mentored and closely worked with 3 groups of senior capstone design students to fabricate and actuate an underwater mount for SONAR and camera on an Autonomous Surface Vessel (ASV)

Extra-Curricular Activities

· **Trekking:** Completed 4 National Himalayan Trekking Expeditions certified by YHAI[10] consisting of more than a week of high altitude(>**14000ft above sea level**) trekking and camping
· **Volleyball:** *(Captain, Institute Volleyball Team, IIT Madras)*
· Spearheaded the institute team for the Inter IIT Sports Meet and All India Jimmy George Volleyball Gold Cup
· Represented IIT Madras as a part of institute Volleyball team at Inter IIT Sports Meet since the freshmen year
· Awarded as the Most Promising Player in All India Inter Collegiate Jimmy George Volleyball Gold Cup 2018
· Secured fourth place in Volleyball at the Inter IIT Sports Meet 2017
· Represented school at zonal level for Tennis & Volleyball

Relevant Coursework

· Decision Making for Robotics
· Reinforcement Learning
· Machine Learning
· Field and Service Robotics
· Motion Planning
· Probability & Statistics
· Nonlinear Control Systems
· Adaptive Control
· Engineering Optimization

Misc Projects

1. "**Diffusion Policy for Long-Horizon Trajectory Planning**" as final course project for CMSC818B: Decision Making for Robotics (Fall 2024)
2. "**Position Hold using Sliding Mode Control for Underwater Robots**" as final course project for ENME743: Applied Nonlinear Control (Spring 2024)
3. "**Depth Control and Stability Analysis of Underwater Robots in Dynamic Wave Environments**" as final course project for ENME665: Nonlinear Oscillations (Spring 2024)
4. "**Adaptive Parameter Estimation for System Identification of Underwater Robots in Unstructured Environments**" as final course project for ENEE765: Adaptive Control (Fall 2023)
5. "**Extended Kalman Filters for Marine Vessel Stabilization under Wave Forces**" as final course project for ENME605: Advanced Systems Control (Fall 2022)
6. "**3D Motion Planning using Markov Decision Process for Underwater Robots under Wave Disturbances**" as final course project for ENAE788V: Motion Planning for Autonomous Systems (Spring 2022)
7. "**Robot Monocular Vision Based Depth Estimation via Transfer Learning**" as part of IEEE RAS Winter School on SLAM in Deformable Environments UTS Sydney 2021

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[10] Youth Hostels Association of India