Deepak Raina

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Current Position

- **Purdue University** — Indiana, USA
  SERB - Overseas Visiting Doctoral Fellow (OVDF) — *January 2022 – Present*
- **Indian Institute of Technology** — Delhi, India
  Prime Minister's Research Fellow (PMRF); Ph.D. in Robotics; GPA: 9/10 — *July 2019 – Present*

Education

- **Indian Institute of Technology** — Jodhpur, India
  Master of Technology in Mechanical Engineering (Robotics); GPA: 9.24/10 — *July 2015 – June 2017*
- **Maharishi Markandeshwar Engineering College** — Ambala, India
  Bachelor of Technology in Mechanical Engineering; GPA:9/10 — *June 2011 – May 2015*

Research Interests

Medical Robotics, Medical Imaging Analysis, Learning from Demonstration, Reinforcement Learning, Tele-robotics, Vision-guided Robotics, Motion-planning, Space Robotics, Vehicle Dynamics

Skills

- **Programming Languages**: Python, C++, HTML
- **Tools**: ROS, Gazebo, MoveIt!, pyTorch, Pybullet, OpenCV, ADAMS; MATLAB, Qt-creator; Solidworks, ANSYS
- **Hardware**: Sawyer robots, Universal robots (UR10, UR5), RG2 gripper, Intel RealSense camera, Haptic devices

Academic Experience

- **Doctoral Research Fellow** — July 2020 - Present
  Indian Institute of Technology, Delhi and Purdue University, USA
  - **Autonomous robotic manipulation of ultrasound probe**:
    - Formulated a Bayesian Optimization (BO)-based search strategy, utilizing *domain expertise*, to efficiently locate high-quality images within the scanning region, eliminating the need for thorough scanning.
    - Proposed incorporating *expert's prior* model in Bayesian Optimization, obtained through expert demonstrations of high-quality probing poses.
    - A novel *expert's image quality metric* model is developed, trained using a dataset of ultrasound images labelled for diagnostic quality by radiologists, which provides image feedback of the region to the BO.
    - Formulated a *expert's kernel* metric, using a dataset of expert's probing maneuvers, for efficient optimization of high-dimensional controllers, including probe position, orientation, and force adjustment
    - Achieved over 50% increase in sample efficiency in comparison to standard BO, with a probe pose and force accuracy of 98.7% and 97.8%, respectively
  - **Ultrasound image quality assessment**:
    - Developed a *supervised CNN model* for analyzing the quality of inter- and intra-patient ultrasound images, using a dataset of highly variable urinary bladder images, labelled for quality by expert radiologists.
    - Using deep variational clustering, developed an *unsupervised CNN model* to classify the ultrasound image quality, to overcome annotation noise in the supervised CNN model.
    - Achieved remarkable accuracy of 93% and 78% for supervised and unsupervised models, surpassing the state-of-the art networks for image quality assessment.
  - **Development of robotic ultrasound probe gripper with jelly dispenser**:
    - Designed a gripper to accommodate ultrasound probes with varying cross-sections (linear, convex, etc.).
    - The operator can easily change different probes without using mechanical tools, cutting down manual effort.
    - Automates the gel dispensing onto the patient's skin, using a camera image to detect the presence of gel, cutting down the robotic procedure time by 20%.
  - **Telerobotic Ultrasound (TR-US) for safety of doctors during COVID-19 (Video)**:
    - Developed the control architecture to teleoperate the ultrasound probe attached to the robotic arm
    - System performance analysis through 21 human trials at All India Institute of Medical Sciences, Delhi

    - Results demonstrated < 0.05 P-value on comparing tele-robotic and manual ultrasound images, gradual improvement of NASA-TLX test parameters, and 0.95 value of reliability index for questionnaire survey.

- **Masters Research Fellow** June 2016 - May 2017
  Indian Institute of Technology, Jodhpur
  - **Impact modeling and control of multi-arm space robot for capturing orbiting objects**:
    - Proposed unified framework for impact modeling and post-impact control of orbiting objects.
    - Post-impact reactionless control for stabilization of the multi-arm robot is proposed, eliminating the need for reaction wheels or thrusters, making it a cost-effective solution.
    - An adaptive reactionless control algorithm is proposed to capture unknown targets.
    - Conducted simulated studies of various impact scenarios, including capture of multi-objects using multiple arms and single object with multiple arms

- **Graduate Teaching Assistant**
  Indian Institute of Technology, Jodhpur and Delhi; Purdue University, USA
  - MFET 442: Programming Robots with ROS Jan-May 2023
  - MCP100: Engineering Visualization and Communication Jan-May 2020, Jan-Dec 2021
  - MCL211: Design of Machines Aug-Dec 2019
  - ME311: Dynamics of Machines and Mechanisms Jan-May 2017, Aug-Dec 2016
  - ME222: Kinematics of Machines and Mechanisms Jan-May 2016
    - Designed and graded questions for homework assignments and quizzes
    - Conducted weekly office hours and attended classes to assist students during in-class doubts.

- **Graduate Mentor**
  Indian Institute of Technology, Jodhpur and Delhi; Purdue University, USA
  - Mentored 1 undergraduate, 1 graduate and 5 intern students in Robotics, AI and Medical imaging analysis
  - Facilitated weekly meetings to track project progress and provide guidance on hardware, software, and tools.
  - The research outcomes were published in international academic journals, conferences and patents.

- **Student Volunteer**
  I-Hub Foundation for Cobotics (IHFC) at IIT Delhi *Dec 2019 - Present*
  - Lead editor of half yearly newsletters.
  - Promoting hub activities in social media, writing proposals for new initiatives

- **Vice President**
  SAE INDIA Collegiate Club at MMEC Mullana *Mar 2014 - 2015*
  - Organized and oversaw activities bringing together automobile enthusiasts, popularizing automobile engineering.
  - Initiated participation of college in various automotive competitions organized by SAE, ASME etc.

- **Team Captain**
  ASME-Human Powered Vehicle Challenge (HPVC) Team *Sep 2014 - Feb 2015*
  - Led a team of 15 students having 5 departmental heads for designing and fabricating a racing tricycle.
  - Managed budget of USD 2000, allocating it to material procurement, transport, and others.

- **Undergraduate Projects**
  M.M. Engineering College, Ambala *Aug 2012 - May 2015*
  - Design and fabrication of Off-Road Vehicle (SAE-BAJA 2015)
    - Designed a roll-cage for this vehicle using design optimization techniques
    - The roll-cage, suspension arms, hub and knuckle was tested against all modes of failure with ANSYS
    - Worked on braking system design and dynamics
    - Prepared DFMEA for the vehicle.
    - Ranked 36th out of 120 teams
  - Design and fabrication of Human-Powered Vehicle (ASME-HPVC 2014).
    - Designed a lightweight and stable HPV using tadpole configuration with Rollover Protection System
    - Performed ergonomics study so that human can apply its peak power with less fatigue
    - The fairing is designed and validated to reduce drag forces.
    - Won 2nd prize in Design

Industrial Experience

- **TCS Robotics Research and Innovation Lab** — Delhi, India
  Researcher - Robotics group — *Dec. 2017 - July 2019*
  - **Robotic packing of Long Distance Carriers (LDCs) (Video)**:
    - Designed new industrial level system to automatically and optimally load parcels in LDC's.
    - Developed collision-free motion planning module for picking parcels from conveyor and placing in LDC's.
    - Helped achieve target filling rate of 12 seconds per LDC.
  - **Palletizer - Automated Truck Loading System (ATLS)**:
    - Designed GUI-based system having a UR-10 manipulator that can load heterogeneous boxes on a pallet.
    - Increased system throughput by directly planning motions using UR-driver by surpassing ROS-MoveIt library.
    - Successfully achieved target output of 12 seconds per pick and place of the box.
  - **Vision-based Control of Redundant Robotic Manipulators (Video)**:
    - Path planning is done in image space using RRT-planner, which helps in satisfying multiple task constraints like FoV limits, joint limits, obstacles, singularities, occlusions etc. in the planning stage itself.
    - A unique mapping between the feature space and the joint space is established by task-priority method, which uses some DoFs for visual servoing whereas redundant DoFs are used for secondary tasks.
  - **Calibration: Robot and Camera**:
    - Developed a package for autonomous calibration of stereo camera with Universal Robots
    - Automated transformation detection that helps with both *eye-to-hand* and *eye-in-hand* setup of the robot.
    - Added testing support feature to verify the generated robot to camera transformation matrix.
    - Dropped calibration time from 20 minutes to 9 minutes, and resource requirement from 2 person to a 1 person.
  - **Chitrakar: Robot Artist (Video)**:
    - Developed a robotic arm to draw a human face as a recognizable non-self-intersecting loop (Jordan curve).
    - Designed motion planning module and novel gripper to complete the drawing within 30 minutes.
    - This work demonstrates the use of robotics to augment humans in executing difficult craft-work.

Relevant Course-Work

Robotics, AI for Cognitive Robot Intelligence, Reinforcement Learning, Computer Vision, Machine Learning, Linear-Systems Theory, Linear Algebra, Multibody Dynamics, Computer-Aided Design, Finite Element Method, Vehicle Dynamics

Achievements

- **Purdue Dean's Travel Grant**: Awarded highly competitive award for supporting my travel to ISMR 2023 in Georgia (USA) and ICRA 2023 in London (UK)
- **DST - AWSAR 2022 Award**: Distinguished as one of the nation's top 100 scientific research stories. I communicated my research on robotic ultrasound in simple language for the common masses.
- **SERB - Overseas Visiting Doctoral Fellowship (2022-2023)**: Among 25 Ph.D. students to be selected across country to spend 1.5 years at Purdue University, USA.
- **Runner-up International Robot Design Competition Award (2021)**: Awarded to our Telerobotic Ultrasound system at ICSR 2021 Robot Design Competition for the COVID-19 innovative response.
- **Director's Honorarium (2021)**: Awarded by Director of IIT Delhi for my efforts in establishing the Technology Innovation Hub (TIH) on Collaborative robotics (Cobotics) at IIT Delhi.
- **Prime Minister's Research Fellowship (2019-2023)**: Among 10 students to be selected across country in Mechanical Engineering. This fellowship is awarded by Ministry of Education (MoE) for persuing Ph.D. at IITs
- **Dassault Systèmes Design Award (2014)**: Awarded 2^{nd} prize in design of human-powered vehicle competition organized by ASME at IIT Delhi.
- **Indira Gandhi Merit Scholarship (2011-2015)**: Awarded by Director of Higher Education for securing 7^{th} rank in 12^{th} state board exams.

Publications

- **Conferences**
  - Robotic Sonographer: Autonomous Robotic Ultrasound using Domain Expertise in Bayesian Optimization. **D. Raina**, S.H. Chandrashekhara, R. Voyles, J. Wachs, S.K. Saha. IEEE International Conference on Robotics and Automation (**ICRA**) 2023.
  - Deep Kernel and Image Quality Estimators for Optimizing Robotic Ultrasound Controller using Bayesian Optimization. **D. Raina**, SH Chandrashekhara, R. Voyles, J. Wachs, S.K. Saha. IEEE International Symposium on Medical Robotics (**ISMR**) 2023.
  - Expert-Agnostic Ultrasound Image Quality Assessment using Deep Variational Clustering. **D. Raina**, D. Ntentia, S.H. Chandrashekhara, R. Voyles, S.K. Saha. IEEE International Conference on Robotics and Automation (**ICRA**) 2023.
  - Learning Robotic Ultrasound through Coaching. M.V. Balakuntala, **D. Raina**, R. Voyles, J. Wachs. Hamlyn Symposium on Medical Robotics (**HSMR**) 2023.
  - Slim U-Net: Efficient Anatomical Feature Preserving U-net Architecture for Ultrasound Image Segmentation, [Paper]. **D. Raina**, K. Verma, S.H. Chandrashekhara, S.K. Saha. ACM International Conference on Biomedical and Bioinformatics Engineering (**ICBBE**) 2022.
  - Comprehensive Telerobotic Ultrasound System for Abdominal Imaging: Development and in-vivo Feasibility Study, [Paper]. **D. Raina**, H. Singh, S.K. Saha, C. Arora, A. Agarwal, S.H. Chandrashekhara, K. Rangarajan, S. Nandi. IEEE International Symposium on Medical Robotics (**ISMR**) 2021.
  - A Novel Image-based Path Planning Algorithm for Eye-in-Hand Visual Servoing of a Redundant Manipulator in a Human Centered Environment, [Paper]. **D. Raina**, P. Mithun, S.V. Shah, S. Kumar. IEEE International Conference on Robot and Human Interactive Communication (**RO-MAN**), 2019.
  - Impact Modeling and Estimation for Multi-Arm Space Robot while Capturing Tumbling Orbiting Objects, [Paper]. **D. Raina**, S.V. Shah. ACM Proceedings of Advances in Robotics (**AIR**), 2017.
- **Journals**
  - USQNet: Deep Learning Model for Enhancing Quality Assessment of Ultrasound Images using Multi-scale and Fine-grained processing, [Under Revision]. D. Raina, S.H. Chandrashekhara, R. Voyles, J. Wachs, S.K. Saha. **IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control** 2023.
  - Tele-robotic ultrasound: an initial feasibility study, [Paper], S.H. Chandrashekhara, K. Rangarajan, A. Agrawal, S. Thulkar, S. Gamanagatti. **D. Raina**, S.K. Saha and C. Arora. World Journal of Methodology 2022.
  - Comprehensive Impact Modeling and Reactionless Control for post-capturing and manoeuvring of orbiting objects using a Multi-arm space robot, [Paper]. **D. Raina**, S. Gora, D. Maheshwari, S. V. Shah. **Acta Astronautica** 2021.
  - Design and Development for Roll Cage of All-Terrain Vehicle, [Paper]. **D. Raina**, R.D. Gupta, R.K. Phanden. International Journal for Technological Research in Engineering (IJTRE), 2015.
- **Workshops**
  - Local and global feature fusion for ultrasound image quality assessment: Towards autonomous ultrasound. **D. Raina**, M.V. Balakuntala, R. Voyles, S.K. Saha. Workshop on Human-centered Autonomy in Medical Robotics, IEEE International Conference on Robotics and Automation (**ICRA**) 2022 [Link]
  - Telerobotic Ultrasound: Towards safer, precise and remote diagnosis of COVID-19 patients. **D. Raina**, S. Nandi, S.K. Saha, C. Arora, K. Rangarajan and S.H. Chandrashekhara. Workshop on Autonomous System in Medicine, IEEE International Conference on Intelligent Robots and Systems (**IROS**) 2020 [Link]
  - Chitrakar: Robotic System for Drawing Jordan Curve of Facial Portrait, [Paper], A. Singhal, A. Kumar, S. Thukral, **D. Raina**, S. Kumar. Workshop on Creativity and Robotics, International Conference on Social Robotics (**ICSR**), 2020 [Link]
  - Reactionless control and target manoeuvring of orbiting object in post-capture phase using a multi-arm space robot. **D. Raina**, S. Gora, S.V. Shah. Workshop on Space Robotics, IEEE International Conference on Robotics and Automation (**ICRA**) 2020 [Link]
- **Book Chapters**
  - Modeling and Estimation of Closed-Loop Impact for Multi-arm Space Robot While Capturing a Tumbling Orbiting Object, [Paper]. **D. Raina**, S. Gora, S.V. Shah. Machines, Mechanism and Robotics, Lecture Notes in Mechanical Engineering, Springer, 2019
- **Patents**
  - Modular Robotic Ultrasound Probe Gripper with Autonomous Gel Dispenser. **D. Raina**, Z. Zhao, R. Voyles, J. Wachs, S.K. Saha, S.H. Chadrashekhara. App. No. 202311002219; Submitted on Jan. 11, 2023
  - Autonomous multi-bin parcel loading system. A. Singhal, H. Kahdilkar, V. Raju, **D. Raina**, V.S. Prasad, S. Thukral, R. Sinha. US2021/0253376A1; Published on Aug. 19, 2019
- **Media Coverage**
  - IIT Delhi, AIIMS New Delhi and Addverb Co-develop Telerobotic Ultrasound System During COVID Times: NDTV, Hindu, Dainik Jagran, News18, IIT Delhi, Times of India
  - Chitrakar: A system that can transform images of human faces into drawings: TechXplore, AtomsTalk