

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 Engg. College** Ambala, India
Bachelor of Technology in Mechanical Engineering; GPA: 9/10 *June 2011 – May 2015*

RESEARCH INTERESTS

Medical Robotics, Physical Human-Robot Interaction, Tele-robotics, Medical Image Analysis, Robot Learning from Demonstration, Space Robotics, Vision-guided Robotics, Motion-planning, 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 prior knowledge in Bayesian Optimization, obtained through expert demonstrations of high-quality probing poses for high image quality.
 - * 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 new kernel metric, Deep Kernel, which is lower dimensional when compared to standard kernels, which leads to a sample-efficient BO framework for substantially optimizing the high-dimensional controller, 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%, surpassing the state-of-the-art networks for image quality assessment
 - **Development of robotic ultrasound probe gripper with jelly dispenser:**
 - * Designed a gripper that can accommodate various types of probes with varying cross-sections at the point of grip. The operator can easily attach and detach different probes using this gripper.
 - * The gripper features an ultrasound gel dispenser that dispenses the gel automatically onto the patient's skin, using a camera image to detect the presence of gel between the probe and the body.
 - **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 (AIIMS), 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.
 - * Numerical studies of different impact scenarios are analyzed in case multi-arm open and closed-loop impacts.
 - * An adaptive reactionless control algorithm is proposed to capture unknown targets.
- **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** *Dec 2019 - Present*
I-Hub Foundation for Cobotics (IHFC) at IIT Delhi
 - Lead editor of half yearly newsletters.
 - Promoting hub activities in social media, writing proposals for new initiatives
- **Vice President** *Mar 2014 - 2015*
SAE INDIA Collegiate Club at MMEC Mullana
 - 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** *Sep 2014 - Feb 2015*
ASME-Human Powered Vehicle Challenge (HPVC) Team
 - 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.

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.

• Tata Automation Limited

Pune, India

Trainee

Jun. 2016 - Jul. 2016

- **BRABO:** This is first made-in-India industrial articulated robot. Designed and performed experiments for design evaluation, validation and testing of this robot.
- **PID Tunning:** Reduced the vibration of robot joints by tuning the PID values for motor-controller setup.

RELEVANT COURSE-WORK

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

ACHIEVEMENTS

- **DST - AWSAR 2022 Award:** Doctoral research story on Tele-robotic Ultrasound distinguished as one of the nation's top 100 scientific research stories.
- **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 pursuing Ph.D. at IITs
- **Dassault Systèmes Design Award (2014):** Awarded 2nd 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 7th rank in 12th state board exams.
- **Letter of Appreciation (2011):** Awarded by Union Minister of India Mr. Anurag Thakur for excellent performance in 12th state board exams

PUBLICATIONS

- **Conference**
 - **Robotic Sonographer: Autonomous Robotic Ultrasound using Domain Expertise in Bayesian Optimization,** [Accepted]
Deepak Raina, SH Chandrashekhara, Richard Voyles, Juan Wachs, Subir Kumar Saha
IEEE International Conference on Robotics and Automation (ICRA) 2023.
 - **Deep Kernel and Image Quality Estimators for Optimizing Robotic Ultrasound Controller using Bayesian Optimization,** [Accepted]
Deepak Raina, SH Chandrashekhara, Richard Voyles, Juan Wachs, Subir Kumar Saha
IEEE International Symposium on Medical Robotics (ISMR) 2023.
 - **Expert-Agnostic Ultrasound Image Quality Assessment using Deep Variational Clustering,** [Accepted]
Deepak Raina, Dimitrios Ntentia, SH Chandrashekhara, Richard Voyles, Subir Kumar Saha
IEEE International Conference on Robotics and Automation (ICRA) 2023.

- **Slim U-Net: Efficient Anatomical Feature Preserving U-net Architecture for Ultrasound Image Segmentation**, [\[Paper\]](#)
Deepak Raina, Kashish Verma, Chandrashekhara SH, Subir Kumar Saha
ACM International Conference on Biomedical and Bioinformatics Engineering (ICBBE) 2022
- **Comprehensive Telerobotic Ultrasound System for Abdominal Imaging: Development and in-vivo Feasibility Study**, [\[Paper\]](#)
Deepak Raina, Hardeep Singh, Subir Kumar Saha, Chetan Arora, Ayushi Agarwal, Chandrashekhara Sh, Krithika Rangarajan, Suvayan Nandi
IEEE International Symposium on Medical Robotics (ISMR) 2021.
- **AI-based Modeling and Control of Robotic Systems: A Brief Tutorial**, [\[Paper\]](#)
Deepak Raina, S.K. Saha
IEEE International Conference on Robotics and Computer Vision (ICRCV) 2021.
- **A Novel Image-based Path Planning Algorithm for Eye-in-Hand Visual Servoing of a Redundant Manipulator in a Human Centered Environment**, [\[Paper\]](#)
Deepak Raina, P. Mithun, Suril V. Shah, Swagat 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**, [\[Paper\]](#)
Deepak Raina, Suril V. Shah
ACM Proceedings of Advances in Robotics (AIR), 2017.

• Journal

- **USQNet: Deep Learning Model for Enhancing Quality Assessment of Ultrasound Images using Multi-scale and Fine-grained processing**, [\[Under Revision\]](#)
Deepak Raina, SH Chandrashekhara, Richard Voyles, Juan Wachs, Subir Kumar Saha
IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control 2023.
- **Tele-robotic ultrasound: an initial feasibility study**, [\[Paper\]](#)
SH Chandrashekhara, K. Rangarajan, A. Agrawal, S. Thulkar, S. Gamanagatti, Deepak 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**, [\[Paper\]](#)
Deepak Raina, Sunil Gora, Dheeraj Maheshwari, Suril V. Shah,
Acta Astronautica 2021.
- **Design and Development for Roll Cage of All-Terrain Vehicle**, [\[Paper\]](#)
Deepak Raina, Rahul Dev Gupta, Rakesh Kumar Phanden
International Journal for Technological Research in Engineering (IJTRE), 2015.

• Workshop

- **Local and global feature fusion for ultrasound image quality assessment: Towards autonomous ultrasound**,
Deepak Raina, Mythra V. Balakuntala, Richard Voyles, Subir Kumar 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**,
Deepak Raina, Suvayan Nandi, Subir Kumar Saha, Chetan Arora, Krithika Rangarajan and Chandrashekhara Sh,
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**, [\[Paper\]](#)
Aniruddha Singhal, Ayush Kumar, Shivam Thukral, Deepak Raina, Swagat 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**,
Deepak Raina, Sunil Gora, Suril 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**, [\[Paper\]](#)
Deepak Raina, Sunil Gora, Suril V. Shah
Machines, Mechanism and Robotics, Lecture Notes in Mechanical Engineering, Springer, 2019

• Patents

- **Modular Robotic Ultrasound Probe Gripper with Autonomous Gel Dispenser** [\[Submitted\]](#),
Deepak Raina, Ziming Zhao, Richard Voyles, Juan Wachs, Subir Kumar Saha, SH Chandrashekhara
App. No. 202311002219

- **Autonomous multi-bin parcel loading system**,
Aniruddha Singhal, Harshad Kahdilkar, Venkat Raju, Deepak Raina, Venkatesh S. Prasad, Sivam Thukral, Rajesh Sinha,
Filed on July 14, 2019

• Theses

- **Impact Modeling and Estimation for Multi-Arm Space Robot while Capturing Tumbling Orbiting Objects**,
Supervisor: Prof. Suril V. Shah,
Department of Mechanical Engineering, IIT Jodhpur

• News

- **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](#)

ACADEMIC PROJECTS

• Course Projects

Masters and Doctorate (Reports and Codes)

- Symbolic motion planning of mobile manipulator in a room environment
- Bayesian state estimation of underwater robot using acoustic observations
- Hand gesture-based control of Music Player using Convolutional Neural Network (CNN)
- Potential field-based motion planning of a serial robot among obstacles
- Image-based visual servoing (IBVS) controller for the UR5 robotic arm
- Solidworks API for triangulation of solid models using Delaunay Triangulation
- Adaptive slicing procedure for layered manufacturing and generate G-Codes
- Acceleration, braking, ride and steering dynamics calculation of Mahindra XUV500 and simulation in AdamsCar

• Design and fabrication of Off-Road Vehicle

SAE BAJA 2015

Lead Designer, Vice-captain

March 2014 - 15

- 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

Captain, Lead Designer

Sep 2013-Feb 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

EXTRA CO-CURRICULAR ACTIVITIES

- Represented M.M. University as a player in All India Inter University Badminton Championship
- Volunteering under National Service Scheme (NSS) for 2 years including 7 days' special camp every 6 months
- Green Belt in Martial Arts

REFERENCES

- **Ph.D. Advisor:** Prof. Subir Kumar Saha, Indian Institute of Technology, Delhi, India; Email: saha@mech.iitd.ac.in
- **Ph.D. Advisor:** Prof. Richard Voyles - Purdue University, West Lafayette, USA; Email: rvoyles@purdue.edu
- **Collaborator:** Prof. Juan Wachs - Purdue University, West Lafayette, USA; Email: jpwachs@purdue.edu
- **Collaborator:** Prof. S.H. Chandrashekhara - All India Institute of Medical Sciences, Delhi, India; Email: drchandrudradioaiims@gmail.com
- **Collaborator:** Prof. Chetan Arora - Indian Institute of Technology, Delhi, India; Email: chetan@cse.iitd.ac.in