

# Gagan Jain

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## RESEARCH INTERESTS

Primarily devoted to Machine Learning and Robotics. I particularly enjoy topics in **Vision, Planning, and Control.**

## EDUCATION

**Indian Institute of Technology Bombay, Bachelor of Technology**

Mumbai, India

**Major:** Mechanical Engineering, **GPA: 9.30/10** with Honors, specializing in Computer Vision

(Expected '22)

**Dual Minors:** Machine Intelligence and Data Science, **GPA: 9.33/10** | Computer Science and Engineering, **GPA: 9.33/10**

- Ranked amongst top 5 in a class of 126 undergraduates (Present)
- **Department Award:** Department Organisational Color, given annually to 1 in 600 students ('21)
- **Institute Award:** Institute Technical Special Mention, for exemplary efforts in institute technical affairs ('20)

## PUBLICATIONS AND RESEARCH EVENTS

- Gokul Mohanraj, **Gagan Jain**, et al., "Application of Deep Convolutional Neural Networks and IR Spectroscopy for the Detection of Drugs and Toxins", International Journal of Engineering and Advanced Technology, Feb. 2021 [Paper](#)
- **Gagan Jain**, Pranav Deo, "Robust Tracking using Model Predictive Control for Self-Driving Cars", oral presentation, Virtual Research Symposium for Students 2021, jointly hosted by IIT Bombay and NTU Singapore [Abstract](#)

## UNDERGRADUATE THESIS PROJECT

**Visual Perception and Situational Awareness for Autonomous Driving** | [Prof. Amit Sethi](#)

(Jul '21 - Present)

*This work attempts to simultaneously detect and precisely locate agents along with their actions in outdoor environments.*

- Performed extensive literature review to learn about 3D network architectures used for multi-class multi-label detection
- Implemented Resnet and YOLO-v3 for real-time detection and cross-stitched networks for simultaneous segmentation
- Employing 3D Retinanet, a pyramid network with focal loss to validate precision metrics reported by Gurkirt et al.
- Currently focusing on the task of agent detection using the idea of optical flow using FlowNet along with YOLO-v3

## RESEARCH EXPERIENCE

**SeDriCa (Self-Driving Car) | Student Research Project** | [Prof. Amit Sethi](#)

(Sep '19 - Present)

*SeDriCa is an interdisciplinary student-driven team of 25+ undergraduates, developing autonomous driving solutions for Indian road conditions. Previously amongst the **top 11** out of 259 participants in the Mahindra RISE Driverless Car Challenge.*

### Computer Vision:

- Devised custom Keras-Retinanet for detection and employed Resnet-152 for training a traffic sign and light classifier.
- Experimenting with the PolyLaneNet architecture for Lane Estimation using Deep Polynomial Regression
- Implemented a unified Multi-task neural network architecture, combining Scaled YOLO-v4 and PSPNet for simultaneous lane estimation, object detection and semantic segmentation, improving speed by 25% and accuracy by 15%

### Localization, Motion Planning and Decision Making:

- Engineered a Simultaneous Localization and Mapping (SLAM) pipeline, improving over GPS-based solutions by 45%, integrating Google Cartographer for building occupancy maps and testing LeGO-LOAM and SUMA++ algorithms
- Implemented RRT\* and Hybrid A\* for path planning and optimized the route by integrating data from Google Maps
- Conceptualized and implemented logical steps to tackle traffic signs and integrated them with the velocity plan. Ideated on ego vehicle decisions and actions related to lane changing, reverse driving and parking execution

### Controls and System Integration:

- Implemented hybrid Model Predictive Control (MPC), discretizing the state space and using a dynamic bicycle model for obtaining optimal control inputs for smooth driving, communicating with planning modules for data using ROS
- Integrated sub-modules for real-time deployment, ensuring availability of sufficient on-board computational resources and tested them under ideal conditions, using CAN module to establish communication with the drive-by-wire system

**Online Reinforcement Learning for Car Driving** [report] | [Prof. Shivaram Kalyanakrishnan](#)

(Jan - May '21)

*Batch RL methods are usually computationally expensive and rely on detailed descriptions of the agent's environment. This work observes the use of online methods using minimal perception by a single dashboard camera to learn driving.*

- Developed an end-to-end architecture using Reinforcement Learning and reward shaping on the CARLA environment
- Benchmarked agent's performance against classical control methods like PID on diverse self-simulated trajectories
- Encoded visual information from drivable regions, traffic signs, and static and dynamic obstacles as numerical features and implemented 2D Tile Coding for state-space discretization and dimensionality reduction
- Designed a stepped reward function, encapsulating the robust driving objective as preferred state-space representations
- Demonstrated a proof-of-concept for vision-based online learning, using the Q-learning algorithm on 4 handcrafted discretized features, achieving collision-free results on CARLA environment for 300+ metres after 15 hours of training

### Counterfeit Drug Detection | University of Cambridge | [Dr. J. Kadiwala](#)

(May - Jul '20)

*Minor amounts of drug adulteration may go undetected upon visual inspection, but IR spectroscopy data analysis is quite robust. This work establishes a new benchmark in detecting adulteration across 200+ drugs, using a single neural network.*

- Performed Data Extraction and Initial Data Analysis (IDA) to extract the IR spectrum of 200 drugs and toxins and performed digital transformations to generate datasets for the detection of counterfeit drugs
- Experimented with conventional models like PCA and SVM for multi-class classification. Applied deep learning techniques like 1D-ConvNets and Siamese NNs for one-shot learning and achieved an unprecedented accuracy of **97%**
- Fine-tuned and generated models robust to variations in noise from differing sources with negligible accuracy loss

## NATIONAL AND INTERNATIONAL PARTICIPATION

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### Traffic Sign Recognition | Bosch's Computer Vision Challenge [[code](#)] | [Inter-IIT Tech Meet 9.0](#)

(Feb - Mar '21)

*Led a team of 10 to develop an intuitive user interface for training, testing, visualizing and explaining deep learning networks*

- Won the bronze medal amongst 20+ IITs, with the IIT Bombay contingent emerging as overall runners-up in the meet
- Trained models including GoogleNet, InceptionNet, and ResNet on GTSRB Dataset, achieving a test accuracy of **95%**
- Employed SMOTE for data balancing, t-SNE plots for visualization, Grad-CAM and LIME for results interpretation

### Intelligent Picking | Flipkart Grid 2.0 Robotics Challenge [[presentation](#)]

(Jun - Sep '20)

*Co-led a team of 7 to develop a warehouse robot capable of autonomously detecting, categorizing and handling products*

- Employed Mobilenet for detection with **92%** accuracy and created an end-to-end simulation pipeline in ROS-Gazebo
- Finished amongst the top 41 teams out of 6061 national participants, clearing the quiz and idea submission round

### Student Design Challenge | American Society of Mechanical Engineers | [Prof. Abhishek Gupta](#)

(Nov '19 - Apr '21)

#### Ball Pick-and-Place Robot | SDC 2019

- Designed a linear-gripper based remote-controlled robot capable of picking, carrying and placing balls of radii 2-12 cm
- Emerged as overall champions amongst 23 teams in the Asia-Pacific Knockout Tournament, received a prize of \$500

#### Energy-Efficient Load Carrier Robot | SDC 2021

- Led a team of 22 to build a AAA-battery operated differential-drive robot for carrying loads upto 5 kg in minimum time
- Placed fourth in the global round amongst 25+ teams from 5 continents, surviving three rounds of strict evaluations

## ACADEMIC HONORS

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- Achieved Advanced Performer's (AP) Grade for exceptional performance in two core courses at IIT Bombay ('20)
- Amongst top **0.05%** in JEE Main out of 1.2 million, top **0.2%** in JEE Advanced out of 0.15 million candidates ('18)
- Amongst top **1%** in National Standard Exams in Physics (NSEP) and Chemistry (NSEC) conducted by [IAPT](#) ('18)
- Secured International Rank **2** in the International Maths Olympiad conducted by [Science Olympiad Foundation](#) ('16)

## SELECTED PROJECTS

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### Transport Rates Prediction and Route Optimization | [Coupa Software](#)

(May - Jul '21)

- Developed learning models for predicting the package delivery cost based on various tabular features on a road network
- Carried out extensive data pre-processing, performing feature selection based on correlation with target cost values
- Achieved a trustworthy uncertainty level of under 3% of average delivery cost, enabling accurate process automation

### Bayesian Multi-task Learning | [Prof. Biplab Banerjee](#)

(Sep - Dec '19)

- Worked on a cost-efficient model for simultaneous segmentation and depth estimation on the Cityscapes dataset
- Developed dense connections between encoder layers, used [attention modules](#) in [U-net](#) architecture for up-sampling

### Fair Algorithms for Classical Bandits | [Prof. Harish Ramaswamy](#)

(Sep '21 - Present)

- Implemented the [FairBandits](#) algorithm for simulated multi-armed bandits and validated fairness and regret bounds
- Extended the idea to bandit settings allowing  $m$  pulls instead on 1 on every time step, observing fair complexity bounds

### Benchmarking Link Prediction Methods on Graphical Networks | [Prof. Abir De](#)

(Sep '21 - Present)

- Evaluated link predictors including simple heuristics like Adamic/Adar Index, linear supervised methods like Node2Vec and deep embedding methods like Graph Convolutional Nets on real networks with varied structural properties

### Algorithmic Image Deblurring | [Prof. Suyash Awate](#)

(Nov - Dec '20)

- Implemented a reverse heat equation based iterative algorithm for image deblurring, as described by [Vinay et al.](#), modeling the problem of blind space-varying blurring as application of uniform heat transfer equation on the image

### Playing Breakout using Deep Reinforcement Learning | [Prof. Abir De](#)

(Mar - May '21)

- Devised a Breakout playing Deep RL agent, using Sensory Processing with access to raw pixels, valid moves and score
- Attained 8-fold increase in reward, training for 1 M iterations using [Double Deep Q-learning](#) with Experience Replay

### Spacecraft Trajectory Tracking using Adaptive Control | [Prof. Sukumar Srikant](#)

(Sep - Nov '20)

- Achieved convergent results, simulating an asymptotically stable integrator back-stepping based control law for robust tracking under uncertainty in inertia parameters, for spacecraft dynamics formulated using Quaternion representation

## Blockchain over a Peer-to-Peer Network | Prof. Vinay Ribeiro

(Aug - Oct '21)

- Built a discrete simulator for a peer-to-peer network, modelled network delays, simulated Proof-of-Work, ensured proper fork merges, and simulated selfish mining and stubborn mining adversaries for block flood-attack testing

## Optimal Maze Navigation | Prof. Shivaram Kalyanakrishnan

(Sep - Oct '20)

- Modelled random 2D mazes as Markov Decision Processes with states, actions, rewards and transition probabilities. Implemented Howard's Policy Iteration, Value Iteration and Linear Programming algorithms to find the optimal path

## POSITIONS OF RESPONSIBILITY

### Team Leader, SeDriCa | Unmesh Mashruwala Innovation Cell

(Apr '21 - Present)

- Leading a key project at the highest-funded technical team of 70+ at IIT Bombay, having won multiple international competitions including IGVC, IARC and ASME SDC, with the vision of introducing autonomous driving in India
- Raised Rs 3.5 M from IIT Bombay's IRCC and Mahindra RISE, and forged relations with multiple academic and industry experts as well as sponsors to ensure state-of-the-art facilities for the team

### Institute Student Mentor | Student Mentorship Programme

(Jun '21 - Present)

- One among the 133 Institute Student Mentors selected out of 300+ applicants on the basis of SOPs, peer reviews and interviews, to help and counsel the incoming freshmen from different academic, cultural and vocational backgrounds

### Undergraduate Teaching Assistant

#### Foundations of Intelligent and Learning Agents | Computer Science and Engineering

(Sep - Dec '21)

- Responsible for designing and evaluating exams and programming assignments, assisting a batch of 300+ students

#### Introduction to Machine Learning | Electrical Engineering

(Jan - May '21)

- Among the only 3 undergraduates selected to tutor for the post-graduate elective course based on HoD's endorsement. Conducted weekly problem-solving sessions, evaluated exams and assignments, and handled project vivas

#### Introduction to Electricity and Magnetism | Physics

(Jan - Jun '20)

- Entrusted with teaching concepts of the introductory course such as boundary value problems, Maxwell's equations to 45 students. Conducted doubt-clearing sessions, assisted in grading and maintaining performance records

### Department Academic Mentor | Student Mentorship Programme

(Jun '20 - Present)

- Selected twice as Department Academic Mentor, mentoring 26 sophomores for 2 years, helping with their academic and general concerns, ensuring their smooth transition in the department after their freshmen year
- Revamped the programme website, maintaining course reviews, research experiences, events information and FAQs

### Department Research Coordinator | Undergraduate Academic Council

(Jun '20 - Apr '21)

- Promoted first-hand research outlook through projects with professors via summer and in-semester research programs, re-furnished Student Reading Groups and organized guidance sessions to help students gain research exposure

## RELEVANT COURSEWORK

Artificial Intelligence	Intelligent and Learning Agents, Fundamentals of Digital Image Processing, Machine Learning: Theory & Methods, Statistical ML & Data Mining, Learning with Graphs, ML for Remote Sensing, Introduction to ML
Robotics and Control	Intelligent Feedback & Control, Adaptive Control Theory, Microprocessors & Automatic Control, Kinematics & Dynamics of Machines, State Estimation*, Machine Design, Engineering Mechanics
Maths and Computing	Design & Analysis of Algorithms, Data Structures & Algorithms, Programming for Data Science, Linear Algebra, Introduction to Blockchains, Calculus, Differential Equations, Numerical Analysis, Optimization

\* Sit Through

## TECHNICAL SKILLS

Programming	C/C++ , ROS, Bash, Python, OpenCV, MATLAB, Tensorflow, Keras, PyTorch, Scikit-learn, OpenAI Gym
Softwares	SolidWorks, CARLA, AutoCAD, OpenMP, Arduino IDE, MSC Adams, Git, MS Excel, OpenFOAM, <del>TeX</del>

## EXTRA-CURRICULAR ACTIVITIES

- Mentored two teams of 5 students each to respectively develop a Policy Gradient based Intelligent Agent to learn to play PacMan and develop a deep learning based OCR under WnCC's Seasons of Code ('20,'21)
- Delivered a lecture on getting started in the field of Analytics and Machine Learning to IIT Bombay freshmen ('21)
- Selected for the prestigious Machine Learning Summer School (MLSS), Taipei, attended lectures and poster events on cutting-edge research in the field, organized by NTU Taiwan ('21)
- Guided two teams of 4 each through the ideation and execution of their Institute Technical Summer Project ('20)
- Qualified Ideation round of Intel Python-Hackfury for pitching a drone-based solution by natural calamities ('19)
- Taught basic mathematics to secondary school students at Asha, an NGO which provides free and quality education to underprivileged children of nearby slums, volunteering under National Services Scheme ('19)
- Developed Techfest's official site as Web Coordinator, IIT Bombay's technical fest, receiving 4.7 M annual hits ('19)
- Participated in the Cyclothon Initiative at IIT Bombay, to spread awareness about the risk of heart diseases ('18, '19)