# Anindya Harchowdhury

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## Research Interest

SLAM, Object Tracking, Motion Planning of AMRs, 3D scene reconstruction, Imitation Learning

## Education

**PhD**
**IITB-Monash Research Academy**
**jointly awarded by IIT Bombay and Monash University** *Jan 2015 –Dec 2020*

**Thesis:** Sparse 3D Sensing and Motion Planning using Nodding LIDAR in Dynamic Environments.
From Nov 2016–May 2018, I spent with the Intelligent Robotics Research Center, Electrical and Computer Systems Engineering department, Monash University as a PhD student.

**Thesis brief:** The thesis concentrates on the problem of object detection, tracking, and motion planning in a dynamic environment, and ensures robust registration in presence of dynamic objects by learning from sensor data. In this process, (i) I first designed and developed a novel, cost-effective **3D LIDAR** and then improvised its sensing mechanism to provide a faster scan update rate than usual 2D Lidars, suitable for dynamic object tracking. The FoV of this sensor can be reconfigured programmatically. (ii) Then, a first of its kind two-stage estimation process is proposed; first stage: real-time **GMM based machine learning algorithm** to **track** and estimate **shape** of **dynamic object(s)**(coarsely) and second stage: using Kalman Filter based framework (for precise estimate) with arbitrary shape and motion primitives from **sparse** 3D data. (iii) As the last contribution, a fast real-time **motion planning algorithm** (*Adaptive BIT**) in the presence of multiple **dynamic objects** in an initially unknown environment is proposed. A physics based simulation framework has been developed to test the capacity of motion planning with varying obstacle density in an environment.

**MS(research)** in E&ECE
**Indian Institute of Technology, Kharagpur** *2011 – 2014*

**Thesis brief:** Designed a "Test Simulator for Satellite based Automatic Identification System". A novel generalized space based observational model is proposed with the advent of an efficient wireless channel access model (SOTDMA) for AIS equipped ships. The ships communicate among each other by forming Ad-hoc network during voyage. Various capacity enhancement techniques of satellite based AIS are developed. Constellation of satellites is found to be effective. A novel SDMA based RF beam steering algorithm is proposed to enhance satellite based reception performance with respect to state-of-the-art.

**B.Tech** in Electronics and Communication Engineering
**WestBengal University of Technology** *2006 – 2010*

**Thesis brief:** A Data acquisition system for liquid level monitoring. Designed entire hardware chain starting from power supply, analog conditioning circuit for the signal received by the sensor, A/D converter circuit, followed by data connection to microcontroller 8051. Further a PC based front end was developed using MATLAB to facilitate bi-directional communication between microcontroller and PC for interested driven liquid level monitoring.

## Employment

**Technical Lead: Mobile Robots** *March 2021 – present*
**The Hi-Tech Roboticsystemz Ltd.**
Projects:

- SLAM during autonomous navigation: Visual or range-based odometry suffers from the lack of environmental features. In large indoor facilities with semi-dynamic environments proprioceptive sensing (e.g. IMU) has a potential to aid to improve Odometry while performing online mapping. The challenge is to update the map autonomously while natural navigation goes for a toss. (on-going)
- Feature-based SLAM in ultra-large warehouse and manufacturing sites: Solved a critical problem of online map switching for robots equipped with resource-constrained host computers. Our map switching algorithm helps robots by not asking to load a very large map at once, but divide

it into many small chunks and load them depending on the navigation requirements. (completed) (video)
- Robust loop closure detection in a dynamic environment: An Adaboost classifier based loop closure detection model, robust to environmental changes is developed for a range-based SLAM system. Further, it has been integrated with a feature-based SLAM implementation. (completed)

**Research Associate**
Indian Institute of Technology Bombay *Jan 2021 – March 2021*

**Internship**
Autonomous Robotics and AI Intern (Ottonomy IO) June 2020 – Sep 2020
Role: Lead a team of cohorts working on Object detection, segmentation and classification on LIDARs and cameras. Scene understanding and activity recognition, AWS cloud integration.

**Junior Research Assistant (sponsor: ISRO)** *Sep 2010 – Mar 2013*
Satellite based AIS relates to satellite based monitoring of ships on voyage in sea around the world. Although vessels moving in sea use AIS system to avoid physical collision by communicating with each other, space based monitoring of them was more a requirement from defense, from national security point of view. I developed a novel simulator for the first time of such kind, which produces composite AIS signal to be received at satellite considering near real time technical challenges (delay, Doppler, oscillator clock variation etc.). This would serve to determine the capacity of satellite based AIS system.

**Junior Research Assistant (sponsor: ISRO)** *Jan 2014 – Apr 2014*
Planar array synthesis is a compute intensive task partly due to the inherently large number of optimization variables and partly for the fact that the fitness function computation is time consuming. A fast computational approach based on the 2D Fast Fourier transform (FFT) is applied on the PSO for the planar array pattern computation. Array factor is calculated using 2D FFT and element excitation are found out using PSO by minimizing a fitness function. The proposed synthesis method provides significant improvements in terms of performance, computational speed, flexibility, and ease of implementation.

**Junior Research Assistant** *May 2014 – Dec 2014*
Passive imaging is a technique being investigated recently in security and surveillance applications. Being a promising solution, millimeter wave radiation of objects are received by radiometer to reconstruct the image of it without using any active illumination on the object. Compressed sensing has been investigated in this application to reduce image acquisition time, making the system highly cost effective. 2D and 3D-FFT have been used in this application for near-field imaging.

## Publication

- Journal
  - Anindya Harchowdhury, Lindsay Kleeman, Leena Vachhani, *"Perception Aware Motion Planning in Dynamic Environments: A Data-driven Approach"*. (under preparation)
  - Anindya Harchowdhury, Leena Vachhani, Lindsay Kleeman, *"Joint Shape and State Estimation of Dynamic Objects using Sparse 3D information"*. (under preparation)
  - Anindya Harchowdhury, Lindsay Kleeman, Leena Vachhani, *"High Density 3D Sensing using a Nodding 2D LIDAR and Reconfigurable Mirrors"*, Elsevier Mechatronics, June 2023, DOI: 10.1016/j.mechatronics.2023.102968 [link] )
  - Anindya Harchowdhury, Lindsay Kleeman, Leena Vachhani, *"Coordinated Nodding of a 2D Lidar for Dense 3D Range Measurements"*, IEEE Robotics and Automation letters, DOI: 10.1109/LRA.2018.2852781 (published in IROS 2018) [link]
- Conference
  - Trishant Roy, Anindya Harchowdhury, Leena Vachhani, *"Anytime Motion Planning: A Motion Planner for Dynamic Environment"*. (pre-print[link])
  - Anindya Harchowdhury, Kalyan Bandyopadhyay, Binay Kumar Sarkar, *"Beam Scanning for Reception Performance Improvement of Satellite-based AIS"*, IEEE International Conference on Aerospace Electronics and Remote Sensing Technology (ICARES), December 2015. [link]

- Anindya Harchowdhury, Binay Kumar Sarkar, "*Passive Millimeter-wave Imaging for Detection of Objects Under Low Visibility*", APSYM, 2014, Cochin, India.
- Anindya Harchowdhury, Kalyan Bandyopadhyay, Binay Kumar Sarkar, Amitabha Bhattacharya, '*Reception Capacity Enhancement of Satellite based-AIS for Different Classes of Ships*", IEEE Conference on Information and Communication Technologies (ICT-2013). [link]
- Anindya Harchowdhury, Lindsay Kleeman, Leena Vachhani, Anindya Harchowdhury, Kalyan Bandyopadhyay, Binay Kumar Sarkar, Amitabha Bhattacharya, "*Generalized Mechanism of SOTDMA and Probability of Reception for Satellite-based AIS*", 5th International Conference on Computers and Devices for Communication, CODEC-2012. [link]

◆ Symposium

- Anindya Harchowdhury, Lindsay Kleeman, Leena Vachhani, *"Simultaneous Obstacle Tracking and Shape Reconstruction of a Dynamic Obstacle using Sparse Depth Data"*, 3rd Cyber-Physical Systems Symposium (CyPhySS 2019), Indian Institute of Science, Bangalore.

## Technical Competencies

**Extensive Experience:** Python, C/C++, ROS1, ROS2, Gazebo, MATLAB, CARLA.
**Experience:** TensorFlow, Verilog, Open3D, Amazon Web Service (AWS), Multi-threading, Boost, Eigen, Open3D, Bash, SolidWorks.
**Tools/Libraries** PCL, OpenCV, Parallel Computing, LaTeX, GIT, Docker, CMake, Inkscape, Mathematica.

## Teaching Assistant /Demonstrator

- Stochastic and Network Control (Autumn 2019-20 with Prof. Ankur Kulkarni)
- Optimization (Spring 2018-19 with Prof. Ankur Kulkarni)
- Mathematical Structures in Systems and Control (Autumn 2018-19 with Prof. S. Srikant)
- Advanced Engineering Data Analysis (S1 2018 at Monash University with Prof. Zixiang Xiong)
- Probability Models for Engineering (S2 2017 at Monash University with Prof. Zixiang Xiong)
- Circuits and Control (S2 2017 at Monash University with Dr. James Saunderson)
- Computer Organization and Programming (S1 2017 at Monash University with Prof. Tom Drummond)
- Games and Information (Autumn 2016-17 with Prof. Ankur Kulkarni)
- Optimization (Spring 2015-16 Prof. Ankur Kulkarni)
- Games and Information (Autumn 2015-16 Prof. Ankur Kulkarni)

## Coursework

**Relevant Courses in PhD**
Introduction to Probability theory, Optimization, Advanced probability for Engineers, Real Analysis, Systems Theory, Advanced Mobile robotics, Modeling of Dynamical Systems, Control of Nonlinear Dynamical System, and Real-time System Design (**Monash University**)
**Relevant Courses in MS**
Linear Algebra and Error Control Coding, Advanced Electromagnetics, Modern Digital Satellite Communication
**Relevant Courses in B.Tech**
Analog Electronics, Digital Electronics, Digital Signal Processing, Digital Communication, Wireless Communication, Microprocessor 8085 and Microcontroller 8051, Data Communication and Networking

## Course Projects (selective)

**Real time Hand-Pose Estimation:** The goal is to predict the 21 joint locations in human hand from depth images captured with poses. **2D CNN** is not directly suitable for **3D hand pose estimation** due to the lack of 3D spatial information. **3D CNN** model taking a 3D volumetric representation of the hand depth image as input can capture the 3D spatial structure of the input and accurately regress full 3D hand pose in a single pass. Proposed a **D-TSDF** based shallow **3D CNN** architecture, that can train the model in real time.

**Real time Pendulum Mimicking:** Designed a real time system that mimics a rotating pendulum; used a pendulum attached with a disk and connected by a shaft for free rotation due to a brushless DC motor (+ optical encoder). It outputs to **Altera DE2 FPGA** board. An IR transceiver system attached at the base of the pendulum's mast and a corner cube reflector is facing it. Pendulum's free end looks like a rectangular slot with a divider that make two unequal slots. Slotted region height matches with that of IR transceiver to infer from reflected signals. Unequal size of two slots helps two decide which direction the pendulum was coming from. This received signal (IR) is input to the **FPGA**. The system outputs a control signal to change the speed and direction of the motor. Designed a real time **PID** control to smoothing the mimicking task based on the control signals.

## Awards or Achievements

- IROS SDC travel grant to present paper in IROS 2018, Madrid, Spain.
- IITB-Monash research fellowship to carry out Doctoral studies (2015-2019) .

## Leadership Activities

- Leader of the `ACBIITB` team in the ARTPARK robotics challenge, 2021. (Moved up to the second stage where 29 out of 130 teams were selected)
- The five member team was tasked to design an AMR with robotic arms to perform janitorial tasks autonomously.

## Invited Talks

- Topic: **Robot Perception and Navigation in Uncertain Environment** on 20/10/2020,
  organizer: TCS Research in front of the research heads from all the research labs of TCS.
- Topic: **Future of Digital Lidar Altimeter for Space Exploration**, on 06/01/2021,
  organizer: TCS Research in front of the research heads from all the research labs of TCS.

## Interests

photography, swimming, soccer, table-tennis, cooking, cycling, traveling, yoga.

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