

# Damanpreet Singh



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## EDUCATION

### Carnegie Mellon University (CMU)

Master of Science in Mechanical Engineering – Research (Concentration: Robotics)

Pittsburgh, PA

May 2023

**Relevant Coursework:** Simultaneous Localization & Mapping (SLAM), Computer Vision, Geometry-based Methods in Vision, Learning for 3D Vision, Convex Optimization, Deep Learning, Machine Learning

### Thapar Institute of Engineering and Technology

Bachelor of Engineering in Mechanical Engineering

Patiala, India

June 2021

## SKILLS

**Languages and Tools:** Modern C++, Python, Git, ROS, CMake, Bash, Docker, MATLAB, SolidWorks, COLMAP, Linux

**Packages:** Eigen, Ceres, Point Cloud Library, OpenCV, GTSAM, C++ STL, Boost, PyTorch, NumPy, SciPy, Matplotlib, Pandas

**Hardware:** Jetson Xavier, Orin, Velodyne Lidar, Eposon IMU, Leopard Imaging RGB, FLIR Boson, Pixhawk, Traxxas, ARDUINO

**Mathematical Concepts:** Advanced Linear Algebra, Vector Calculus, Probabilistic Methods, Kalman Filters, Factor Graphs

## EXPERIENCE

### The Airlab & Biorobotics Lab, CMU

Graduate Research Assistant (Prof. Sebastian Scherer, Dr. Mathew Travers)

Pittsburgh, PA

Sep 2021 – May 2023

**Project:** Heterogeneous multi-robot system for exploration in unstructured subterranean environments (**MMPUG, DARPA-SubT**)

#### SLAM Implementation and Dataset Management (ICCV '23 workshop)

- Implemented and evaluated **4** SOTA SLAM algorithms - **LIO-SAM, LOAM, FAST-LIO, CLINS** on **SubT-MRS** dataset
- Integrated real-time point cloud colorization in **SuperOdometry** by field-of-view analysis between RGB camera and LIDAR
- Co-led team of **5** in acquiring a **2 TB SubT-MRS** SLAM dataset, comprising **4** robots, **5** sensors, and **5** locations
- Designed Python scripts for dataset cleaning, statistics generation, PyTorch DataLoader, and dataset pip package integration

#### Open-Set Vocabulary Inter-Object (O2O) 3D Affordance Prediction in Point Clouds

- Enabled natural language query-driven affordance prediction in point clouds, reaching **90%** performance relative to **SOTA**
- Performed ablation study for point cloud architectures: **PointNet, PointTransformer**, and LLM architectures: **CLIP, CG3D**
- Currently advancing **O2O-Afford** to open-set vocabulary-based inter-object prediction, utilizing sim-in-the-loop training

#### Systems Engineering

- Developed C++ algorithm for generating SNR graph for radios in multi-robot setup, employing Websockets and ROS-DDS
- Innovated planning constraints using spanning trees in SNR graph, increasing exploration distances by **90%** against SOTA
- Devised **2** behavior trees for switching between **8** autonomy modes in a multi-robot system with 3 UGVs and 2 Spots
- Integrated and calibrated **FLIR-Boson** thermal camera into sensor stack with **<25 ms** time sync delay and **60 Hz** frequency

## ACADEMIC PROJECTS

### 3D Rendering using Neural Radiance Fields (NeRF)

Spring 2023

- Implemented 3D volume and surface reconstruction pipelines in Pytorch3D, using Neural Radiance Fields
- Extended baseline with Phong relighting and hierarchical point sampling

### Learning-based Single View to 3D Reconstruction

Spring 2023

- Designed image to 3D reconstruction using convolutional and MLP networks, for **voxels, meshes, and point clouds**
- Achieved object reconstructions with **0.88 F1** score and extended the network for occupancy queries

### Absolute Conic-based Single view to 3D Reconstruction

Fall 2022

- Designed **2** single image-based camera intrinsics calibration routine using Image of Absolute Conic and vanishing points
- Designed image-based 3D reconstruction using plane annotations and camera intrinsics, with Shapely in Python3

### MNIST Diffusion

Spring 2023

- Designed denoising diffusion probabilistic model (**DDPM**) for **MNIST** number dataset, using Pytorch in Python3
- Produced **80%** generation, for 36 sample sets of MNIST numbers, using **10,000** diffusion timesteps

### Multi-view Reconstruction

Fall 2022

- Built structure-from-motion (SfM) employing perspective-n-point and triangulation, using Numpy and OpenCV in Python3
- Extended baseline to improve camera extrinsics computation, leveraging Bundle Adjustment

### Feature Extractor Voting for Visual Inertial Odometry

Spring 2022

- Incorporated **SuperPoint** feature extractor into frontend of **VINS-MONO**
- Created feature voting and fusion algorithm for SuperPoint and classical features, reducing odometry failure cases by **~40%**

## PUBLICATIONS

- Shibo Zhao, **Damanpreet Singh**, Sebastian Scherer et. al. "SubT-MRS: A Subterranean, Multi-Robot, Multi-Spectral and Multi-Degraded Dataset for Robust SLAM", Submitted to ICCV 2023
- Namya Bagree, Charles Noren, **Damanpreet Singh**, Matthew Travers, and Bhaskar Vundurthy. "High Speed Convoy in Unstructured Indoor Environments" IFAC World Congress, 2023