📌 Project Documentation: Screw Segmentation using PointNet++

Objective

To build a real-time **3D screw segmentation system using PointNet++** that can:

- Identify and segment a single screw among background noise.
- Achieve high inference speed and accuracy. **(99.01)**
- Be used in robotic applications for precise grasping.

Dataset Overview

Raw Data Format (.txt)

- Each file contains variable-length point clouds (e.g., ~221,928 points)
- Format per line:

```
css                                                    Copy  Edit

x, y, z, label, nx, ny, nz
```

Labels:

- 0 = background
- 1 = screw

Preprocessing

Converted Format (.npz)

- Downsampled to fixed-size 8192 points per sample
- Saved in preprocessed_data/sample_000.npz to sample_297.npz
- Contents per file:

points: shape (8192, 6) # **[x, y, z, nx, ny, nz]**

labels: shape (8192,) # **0 or 1**

Model Architecture

Network: Based on **PointNet++ semantic segmentation architecture**

- **Input:** [B, 6, N]
- **Output:** [B, N, 2]
- **Input Channels:** 6 (xyz + normals)
- **Output Classes:** 2 (background, screw)

The PointNet++ implementation is **custom-adapted** for this task:

- Modified input channels to accept **6D features**
- Adjusted output layers for **binary segmentation**
- Optimized training for **screw-background imbalance**

Training

Framework: PyTorch

- **Dataset loader:** ScrewSegTxtDataset
- **Optimizer:** Adam
- **Learning rate:** 1e-3
- **Batch size:** 16
- **Epochs:** 20

- Final model: **pointnet2_screw_segmentation_final.pth**

Inference

Predicting a Sample:

- Load a sample .npz file
- Format input for PointNet++ as [1, 6, 8192]
- Get predicted labels from model output

Visualization using Open3D:

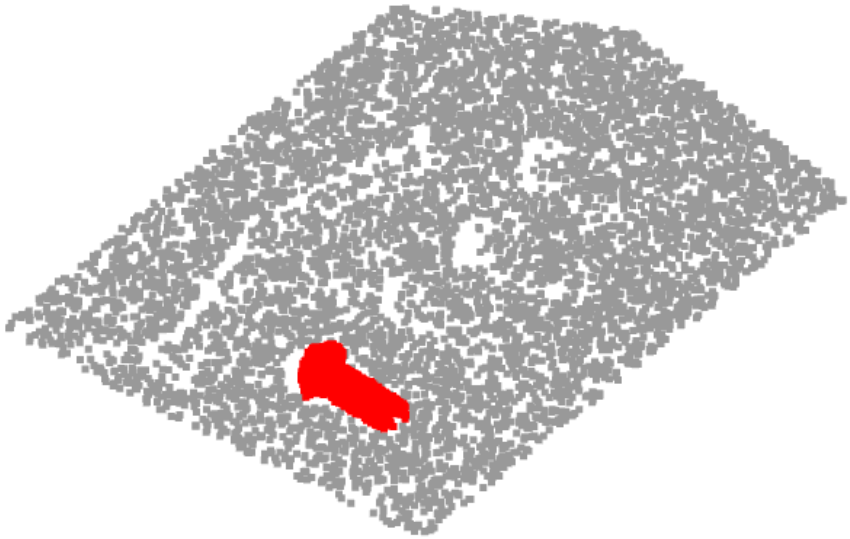
- Color background as gray [0.6, 0.6, 0.6]
- Color screw as red [1.0, 0.0, 0.0]
- Visualize using o3d.visualization.draw_geometries

Results

Input Points: 8192

Classes: Background (0), Screw (1)

Example Output: 969 screw points detected in sample



Compatibility & Requirements

- **Python**: Version 3.10.11
- **PyTorch**: Version 2.7.1
- **CUDA**, **Open3D**, **Matplotlib**
- **Operating System**: Windows 11 Pro
- **Environment**: VS Code
- **Model**: Custom-modified PointNet++ for binary segmentation with 6D input features (xyz + normals)
- **Dataset**: Preprocessed .npz files of 8192 points each, converted from raw .txt format
- **Model Output**: pointnet2_screw_segmentation_final.pth