A Comparative Study Using the ModelNet Dataset for Point Cloud Classification Using Different Machine Learning and Deep Learning Models

UNIVERSITY OF DELAWARE

Introduction

- Introduction to Point cloud.

Why Point Cloud

- Discuss about importance of Point Cloud.

Data Processing and Visualization

- Analyzing and Sampling the data.

Machine learning Models

- Random Forest, MLP Classifier, CNN, and PointNet Classification.

Introduction

- Point cloud data, representing a set of data points in three dimensional , is widely used in various fields such as augmented reality, computer vision and robotics.
- In this project, we aim to perform a comparative study of different machine learning and deep learning models for point cloud classification using ModelNet dataset.
- The ModelNet dataset consists of CAD models from 40 different categories, including commonly used objects like chair,bed,desk and sofas.

Why Point Cloud?

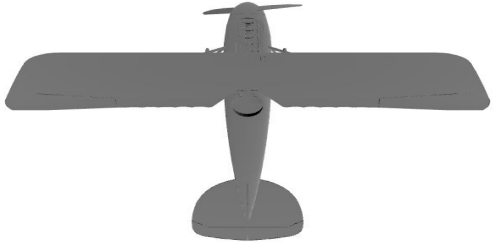
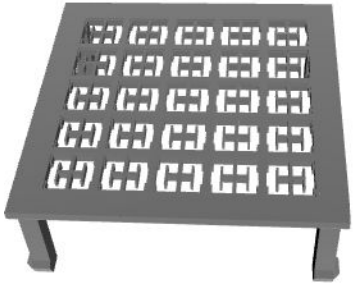
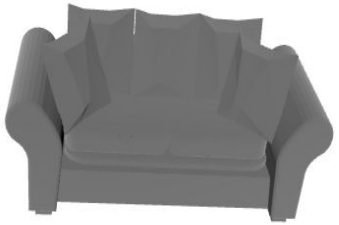
- Point cloud provide a three dimensional representation of objects and environments, they capture the spatial coordinates of individual points in 3D space. This allows the preservation of the object's 3D structure, which is not fully captured in 2D images.

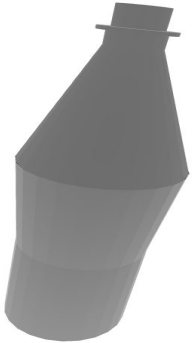
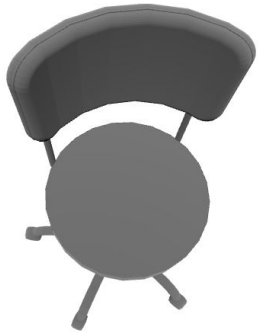
- Point clouds are derived from various sensing technologies such as lidar or 3d scanning. These technologies enable the capture of real world data with high accuracy.

Data Processing and Visualization

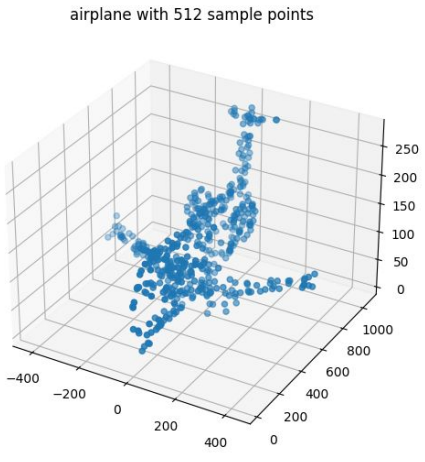
- After analyzing the modelnet40 dataset we took a small sample of 10 objects from the dataset to work on models.
- The data files that are present in the dataset are in object file format(.off) and we use trimesh to load the files and we extract 512,1024,2048 samples individually from the data.
- We have 5102 train points and 1000 test points of total for this objects.

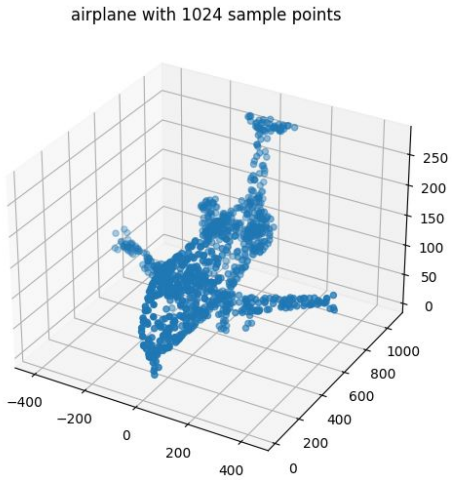
Objects in Dataset

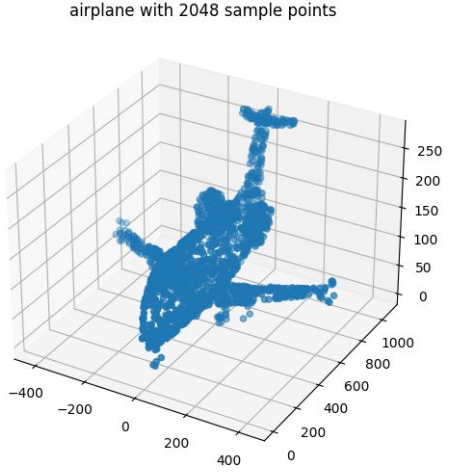




Visualization of objects with different sample points

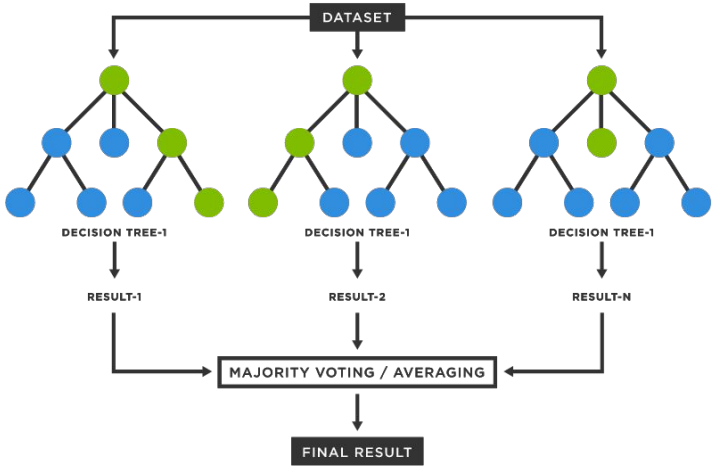




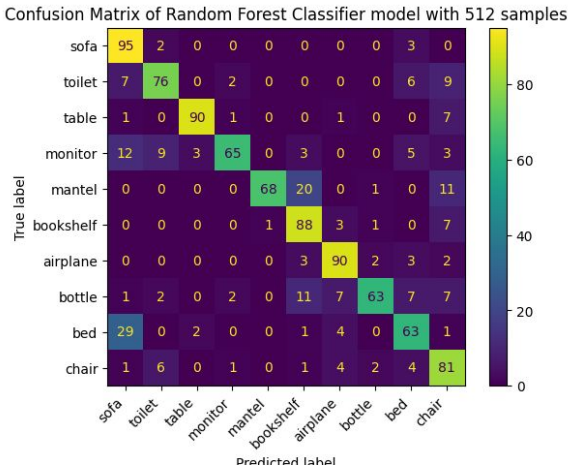


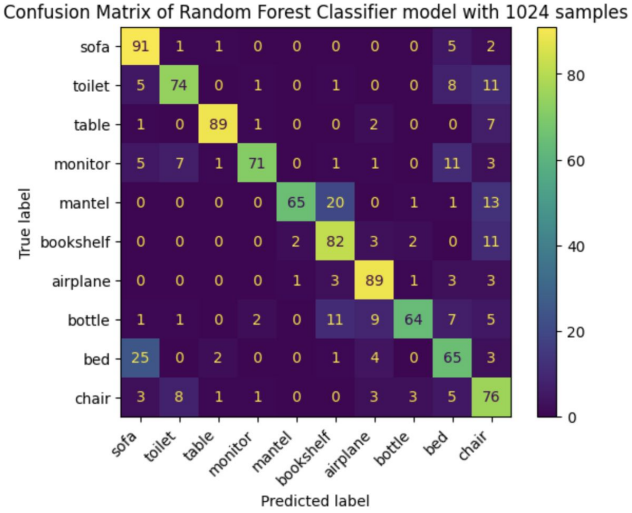
Machine Learning models: Random Forest Classifier

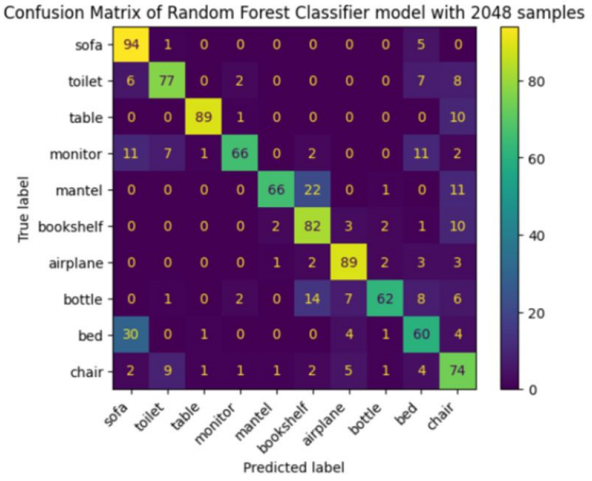
- In this project, we used random forest classifier for point cloud classification using modelnet dataset.
- This classifier combines multiple decision trees to make predictions.
- Point cloud contains large number of data points in 3D, Random forest classifier can handle high dimensional data effectively. We have flattened the data points in 2D and achieved 76% accuracy.



Confusion Matrix of Random Forest Classification Model

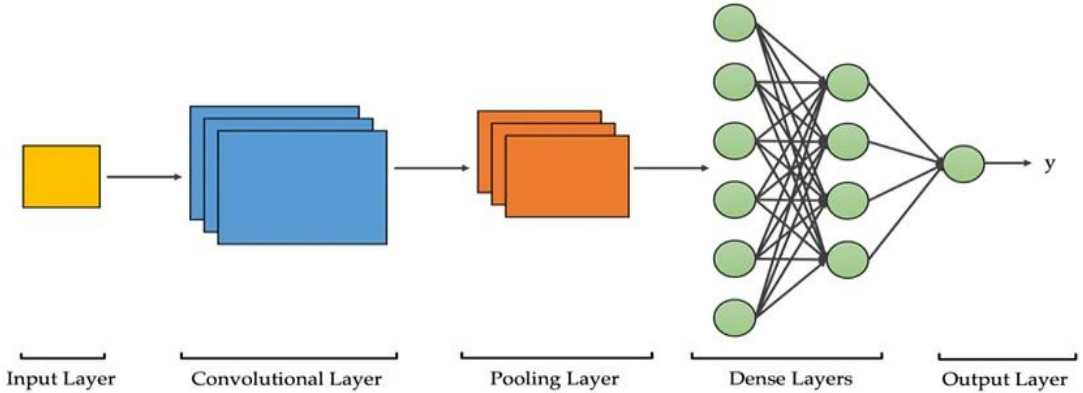




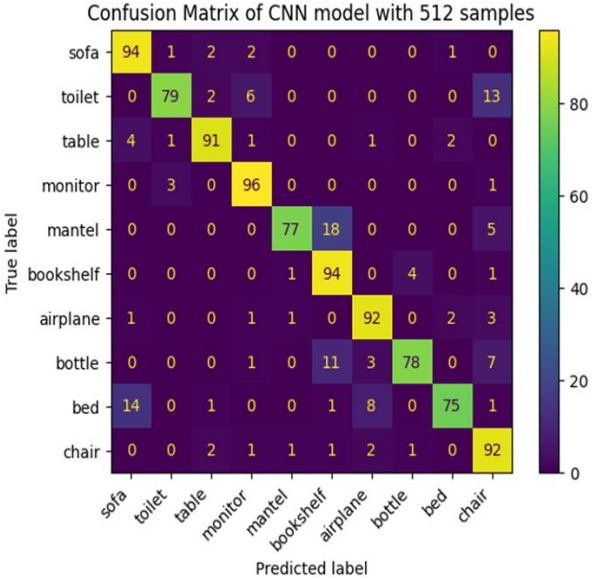


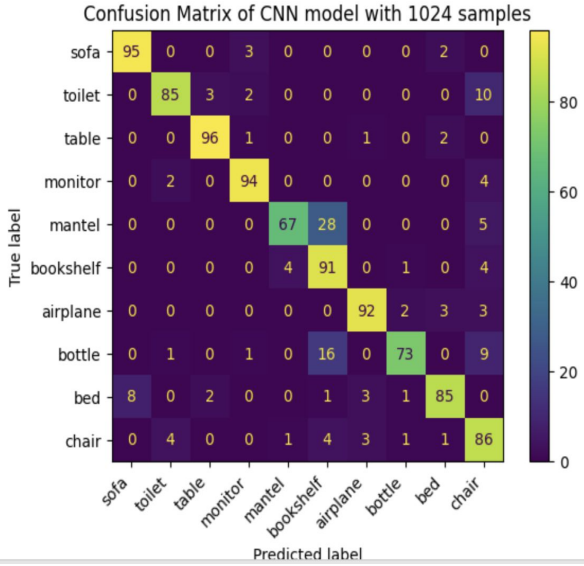
CNN(Convolutional Neural Network)

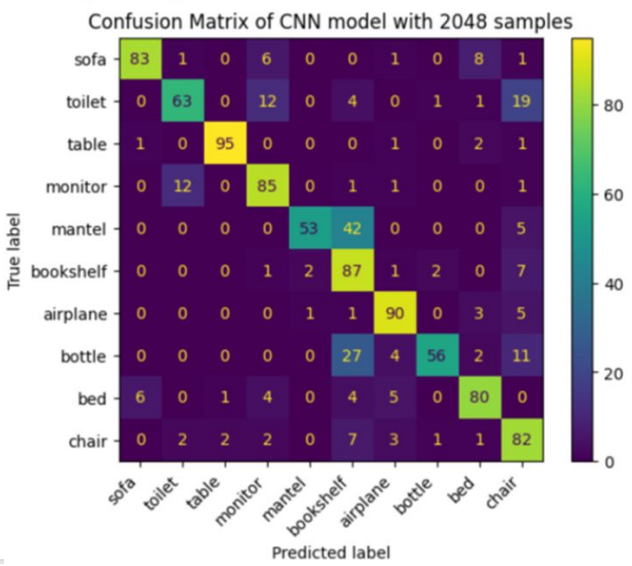
- CNN is a network architecture for deep learning, which is useful for finding patterns in images to recognize objects, classes, and categories.
- We used Conv2d layers, global max pooling and dense layers with activation functions such as ReLU and Softmax to build the model.



Confusion Matrix of CNN Model

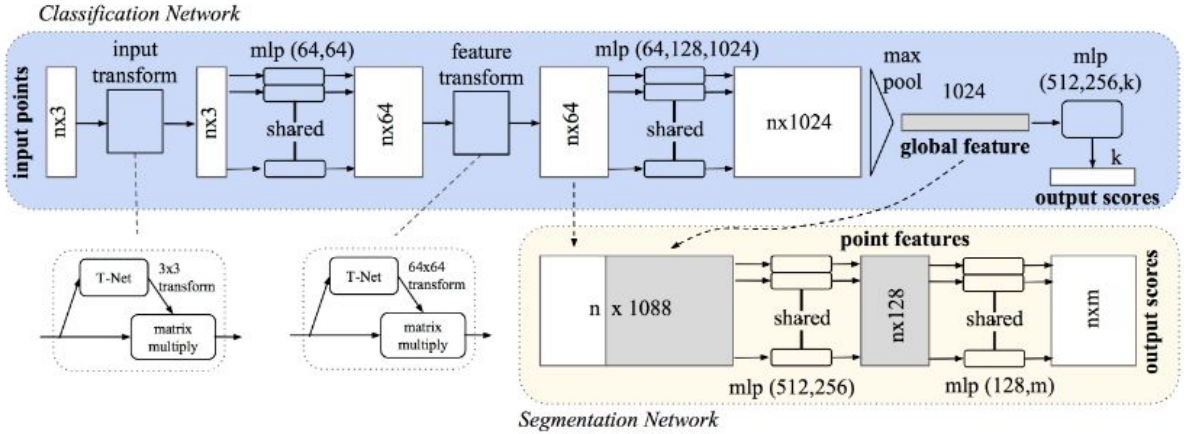






PointNet

- PointNet is a deep learning architecture specifically designed for processing unordered point clouds, where the order of the points does not matter.



PointNet contd…

- The use of pointNet in this project allows for direct classification without transforming data into other representations.
- It can handle point clouds with varying number of points, making it suitable for datasets like ModelNet,where the number of points may vary across different CAD models.

Prediction using pointnet with 512 samples

```
1/1 [==============================] - 0s 141ms/step
```

predicted label: sofa, original label: sofa

predicted label: bottle, original label: toilet

predicted label: bed, original label: bed

predicted label: sofa, original label: sofa

predicted label: bookshelf, original label: bookshelf

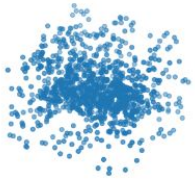
predicted label: sofa, original label: sofa

predicted label: bottle, original label: monitor

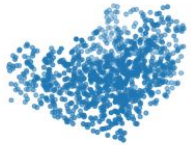
predicted label: sofa, original label: sofa

Prediction using pointnet with 1024 samples

predicted label: bookshelf, original label: bookshelf



predicted label: sofa, original label: sofa



predicted label: airplane, original label: airplane

predicted label: airplane, original label: airplane

predicted label: table, original label: table

predicted label: chair, original label: chair

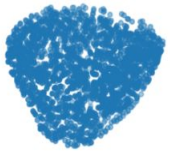
predicted label: toilet, original label: toilet

predicted label: airplane, original label: airplane

Prediction using pointnet with 2048 samples

```
1/1 [==============================] - 1s 535ms/step
```

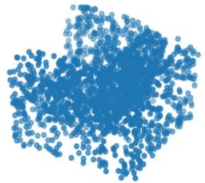
predicted label: monitor, original label: toilet



predicted label: airplane, original label: monitor

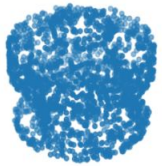
predicted label: monitor, original label: sofa

predicted label: sofa, original label: sofa



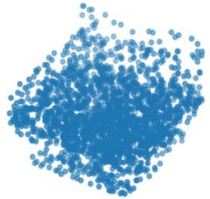
predicted label: airplane, original label: airplane

predicted label: bottle, original label: bottle



predicted label: monitor, original label: monitor

predicted label: bed, original label: bed



References

1. H. Su, S. Maji, E. Kalogerakis, E. Learned-Miller. Multi-view Convolutional Neural Networks for 3D Shape Recognition. ICCV2015.
2. Siamak Ravanbakhsh, Jeff Schneider, Barnabas Poczos. Deep Learning with sets and point clouds.
3. Charles R. Qi, Hao Su, Kaichun Mo, and Leonidas J. Guibas. PointNet: Deep Learning on Point Sets for 3D Classification and Segmentation. CVPR 2017.
4. A. Garcia-Garcia, F. Gomez-Donoso†, J. Garcia-Rodriguez, S. Orts-Escolano, M. Cazorla, J. Azorin-Lopez. PointNet: A 3D Convolutional Neural Network for Real-Time Object Class Recognition.
5. Shuaifeng Zhi, Yongxiang Liu, Xiang Li, Yulan Guo Towards real-time 3D object recognition: A lightweight volumetric CNN framework using multitask learning Computers and Graphics (Elsevier)
6. Panos Achlioptas, Olga Diamanti, Ioannis Mitliagkas, Leonidas Guibas. Learning Representations and Generative Models for 3D Point Clouds, arXiv 2017.

Thank you!