3D Point Cloud Registration using Gaussian Mixture Models

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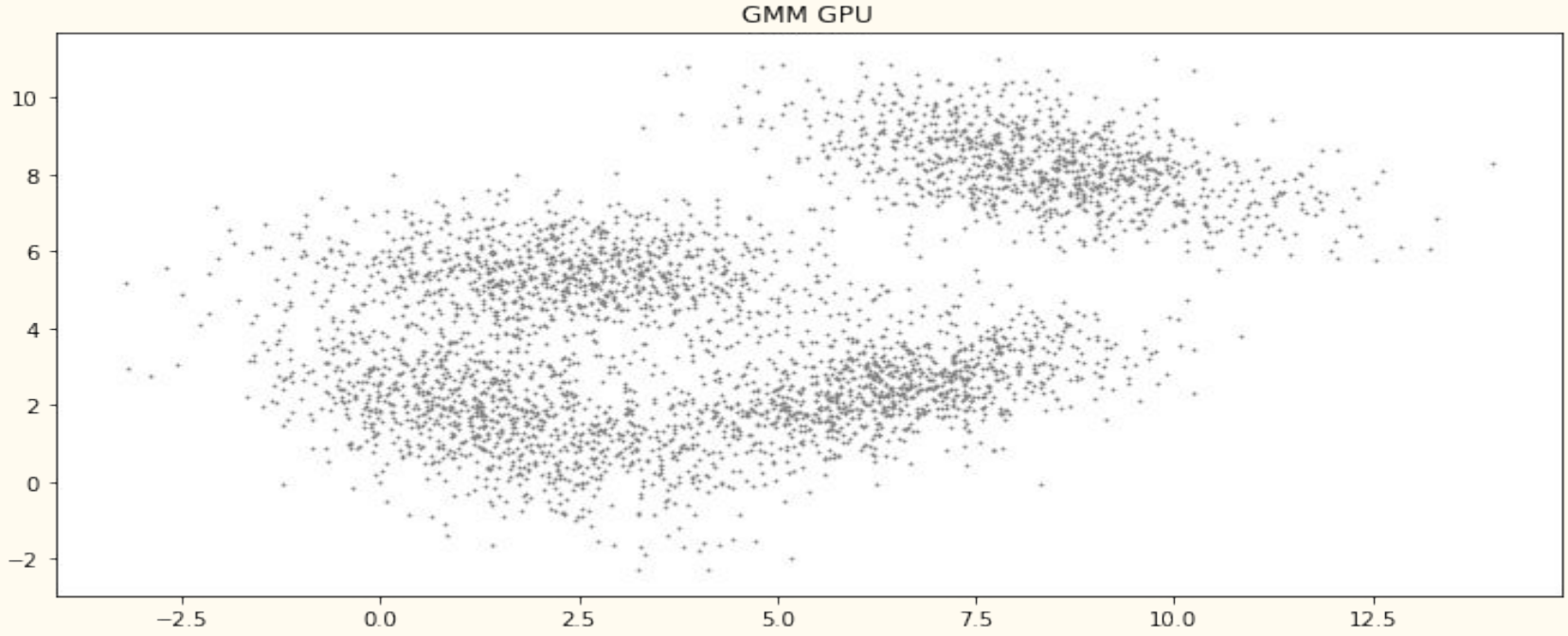
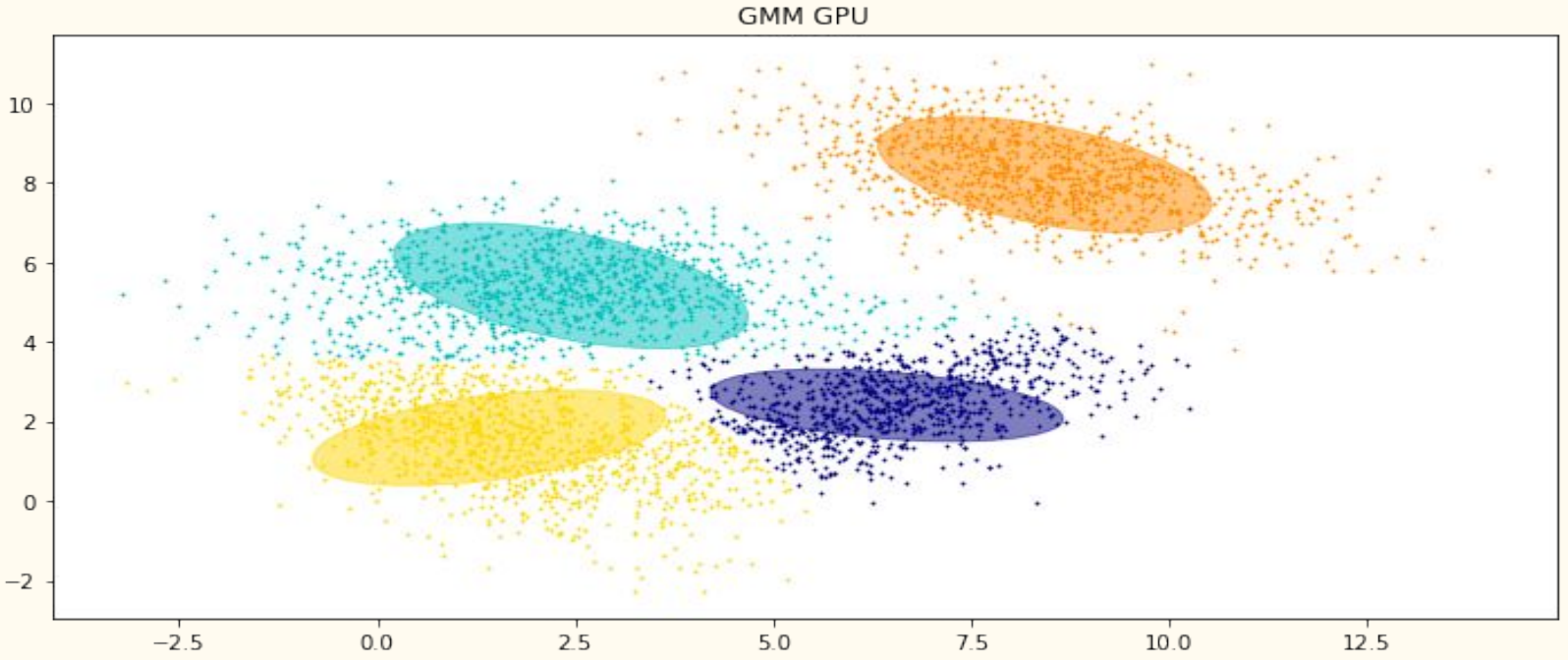
Introduction

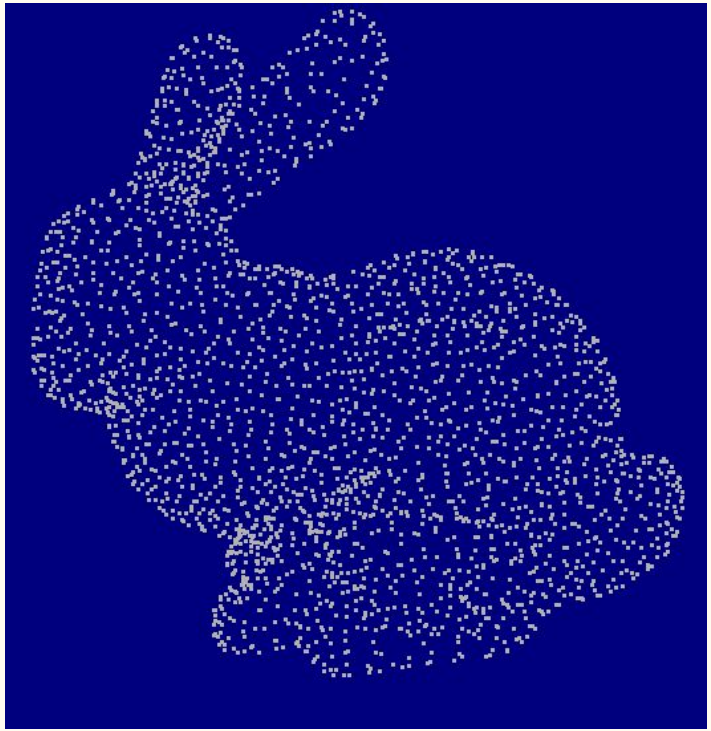
Clustering: 2-D Gaussian Mixture Models



Clustering: 2-D Gaussian Mixture Models

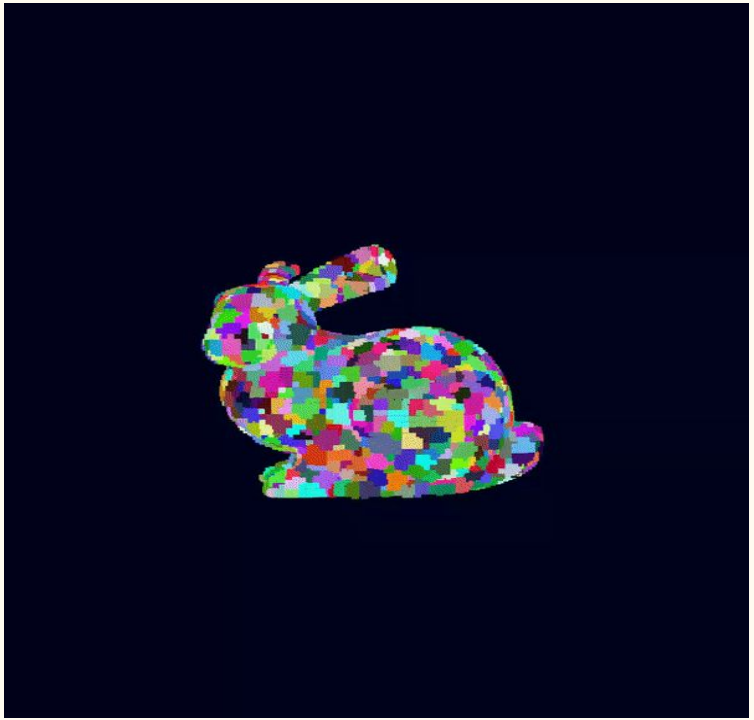


Clustering: 3-D Gaussian Mixture



Clustering: 3-D Gaussian Mixture

100 GMM Components



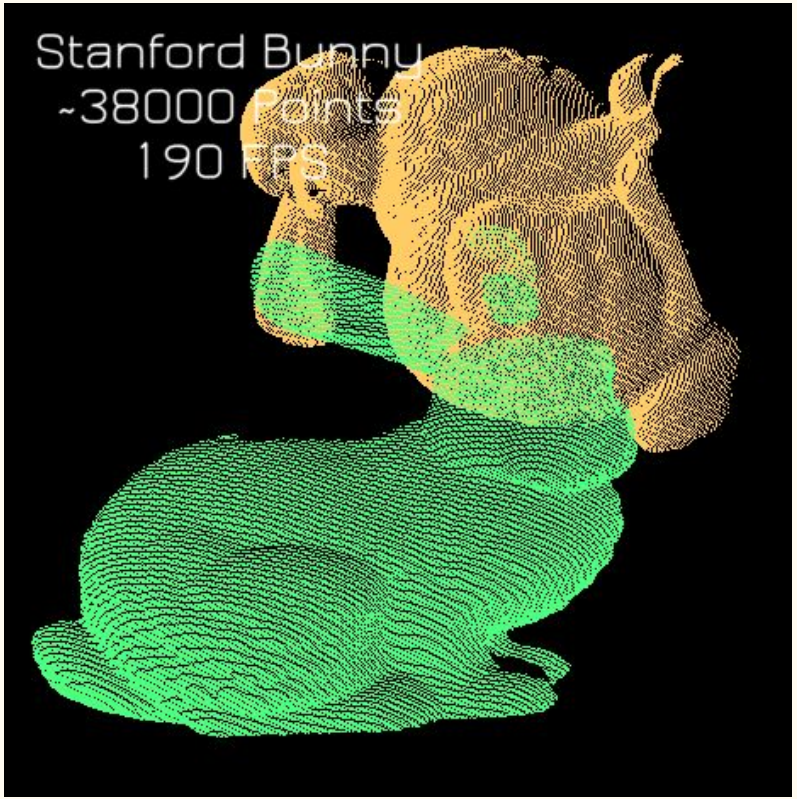
800 GMM Components

Point Cloud Registration

Naive Solution: Iterative Closest Point

Overview:

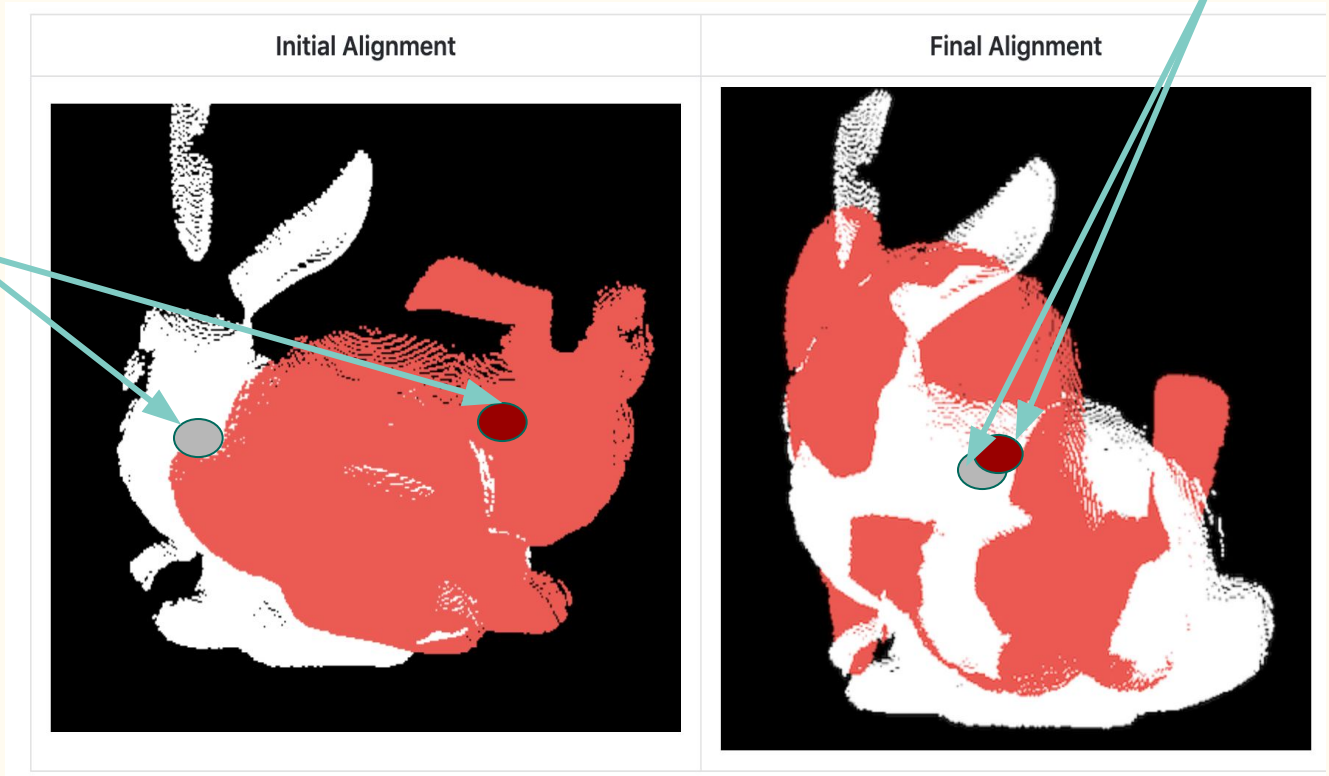
- **POINT TO POINT Approach**
- Align each **source** **point** with its nearest neighbour **target** **point**
- Prioritizes aligning **centroids/center of masses** of point clouds.



Naive Solution: Iterative Closest Point

Aligned Center of Masses

Center of Masses



Better Solution: Use Gaussian Clustering

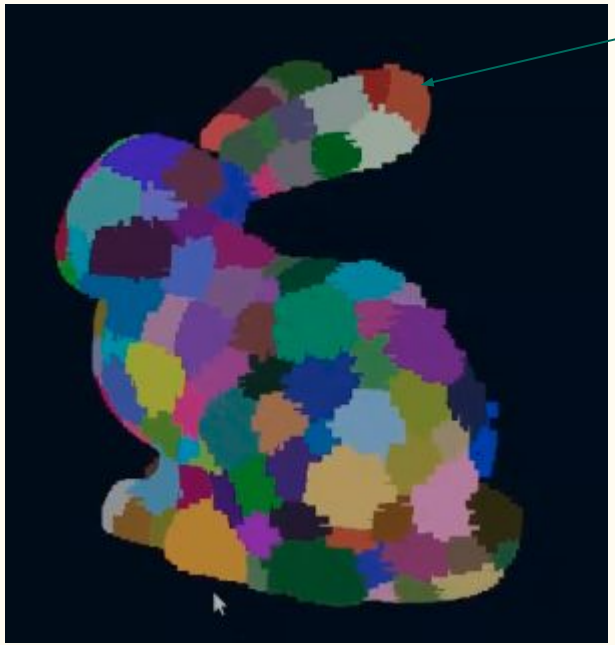
Main Idea:

- Instead of **POINT to POINT**, do **CLUSTER to CLUSTER**
- Use **Gaussian Mixture Model Clustering** to identify **clusters**
- Each cluster is **geometrically similar**

Better Solution: Use Gaussian Clustering

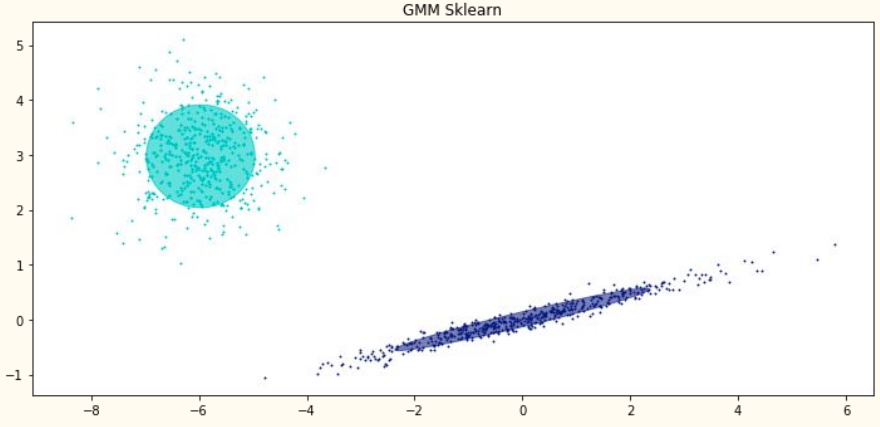
Main Idea:

- Instead of **POINT to POINT**, do **CLUSTER to CLUSTER**
- Use **Gaussian Mixture Model Clustering** to identify **clusters**
- Each cluster is **geometrically similar**

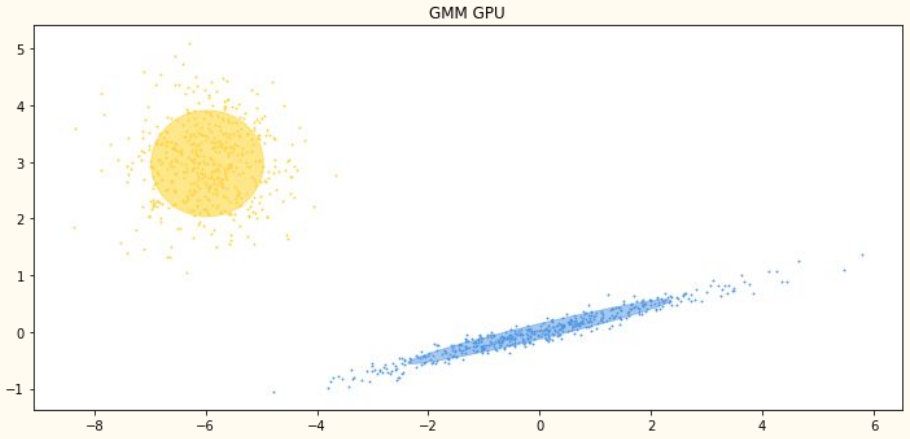


Match **ears** to **ears** instead of **points** to **points**

Our Implementation vs Sklearn (Popular Library)



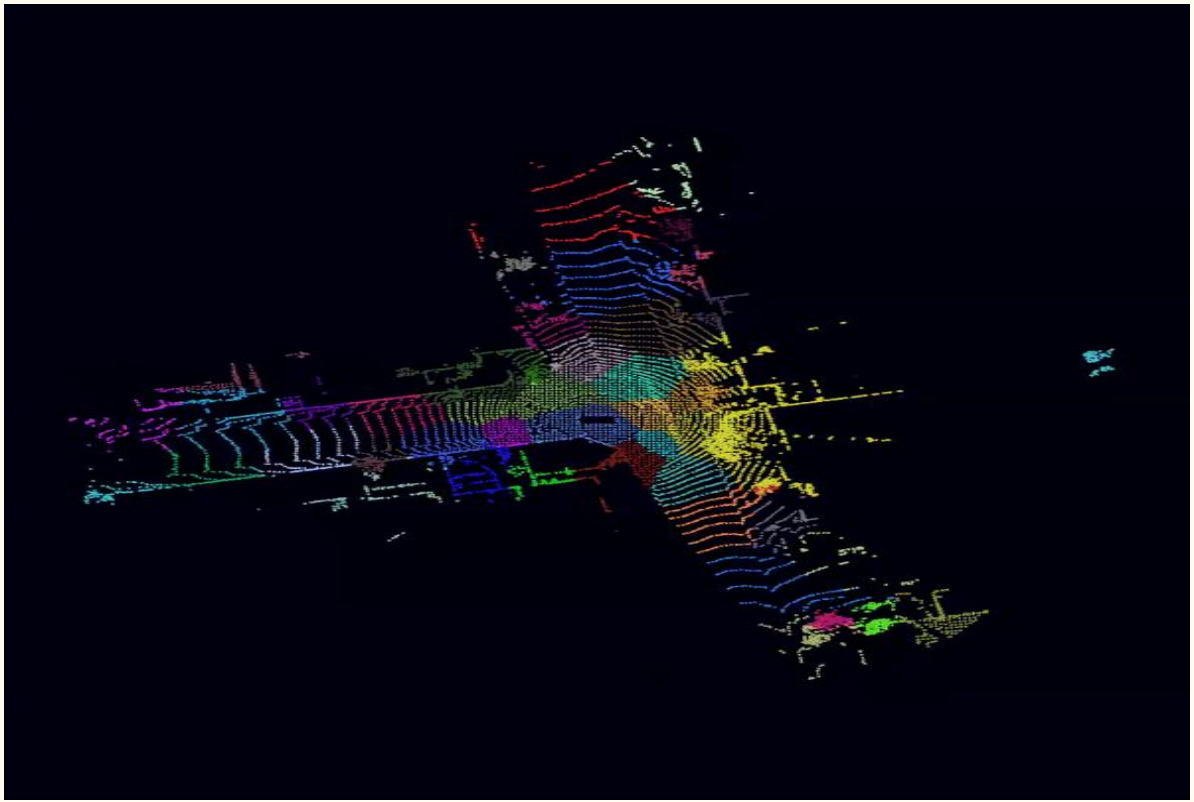
Sklearn Implementation



Ours

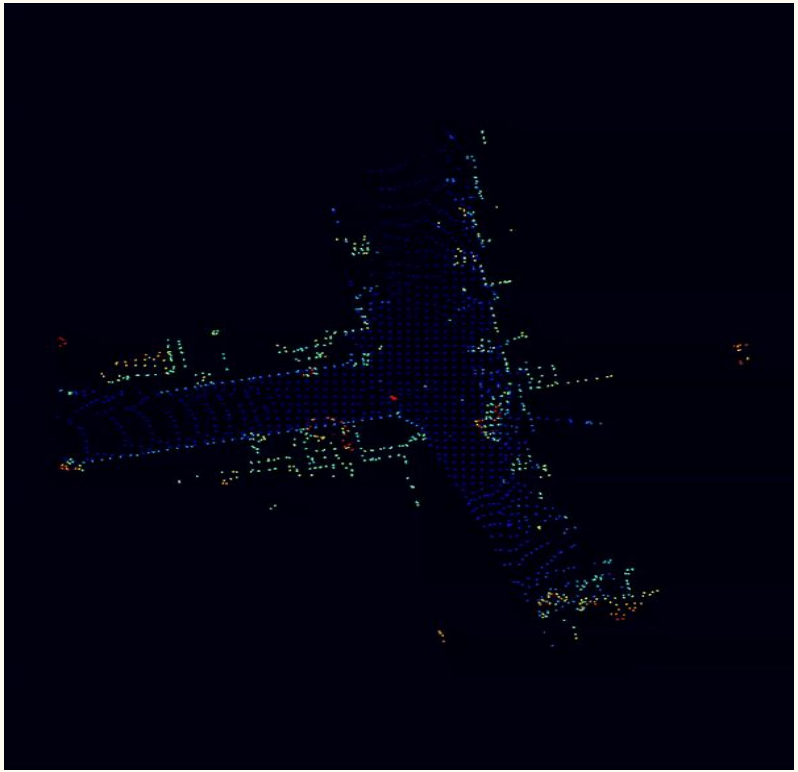
Use Cases

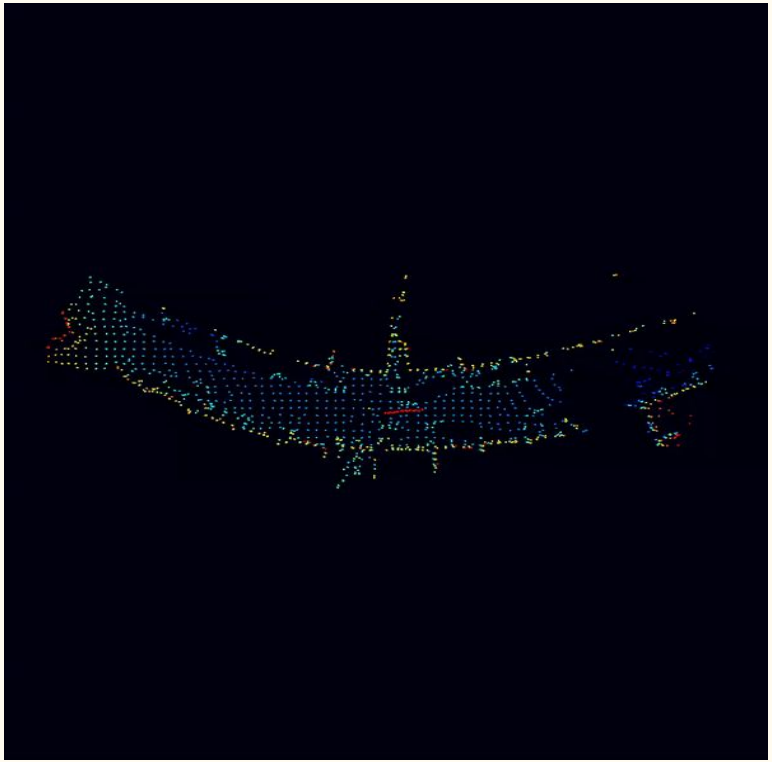
Use Case: Unsupervised Point Cloud Segmentation



Mixture Models on Waymo Dataset

Use Case: Real-Time Localization

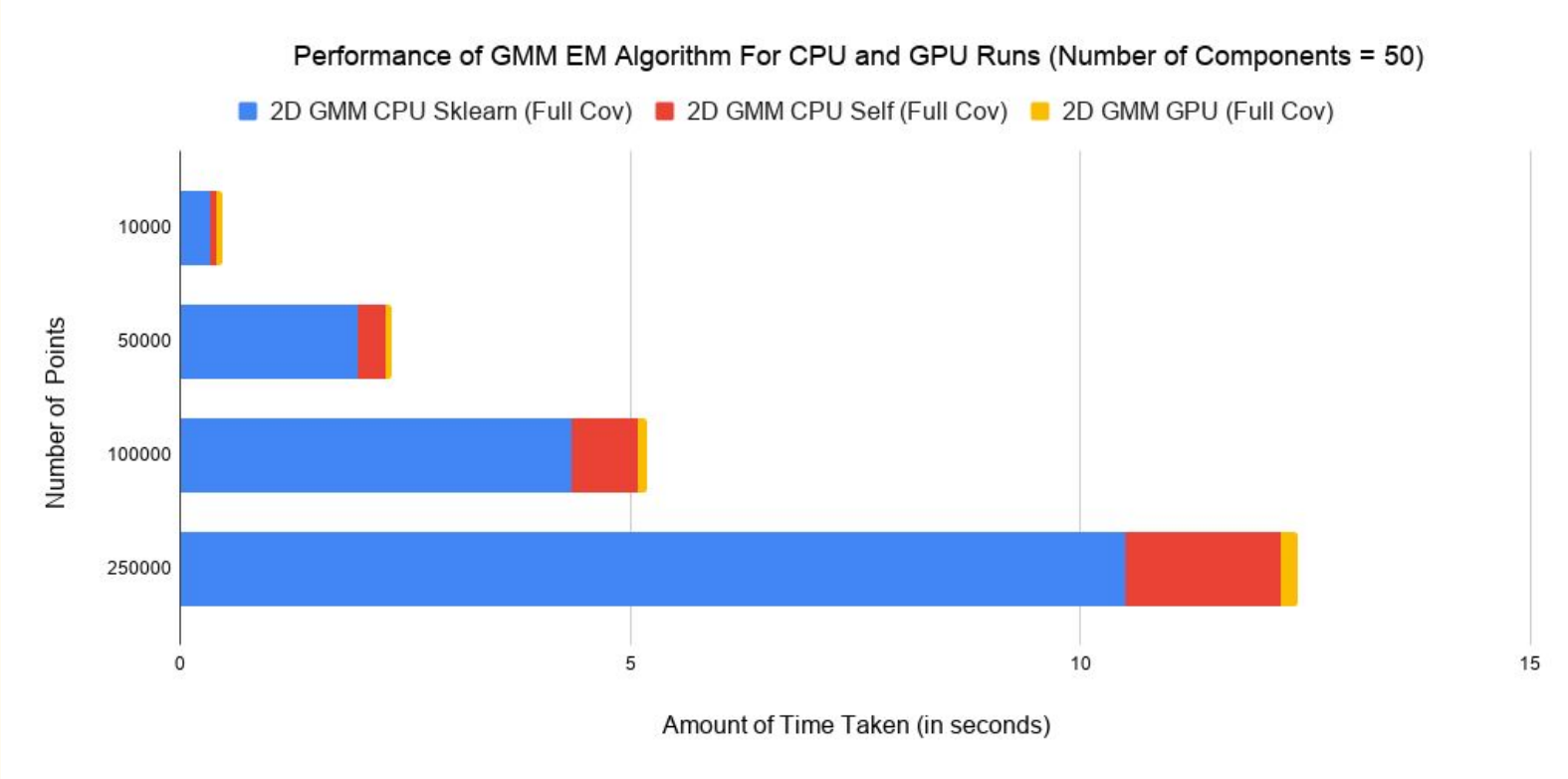




Localization on Waymo Dataset

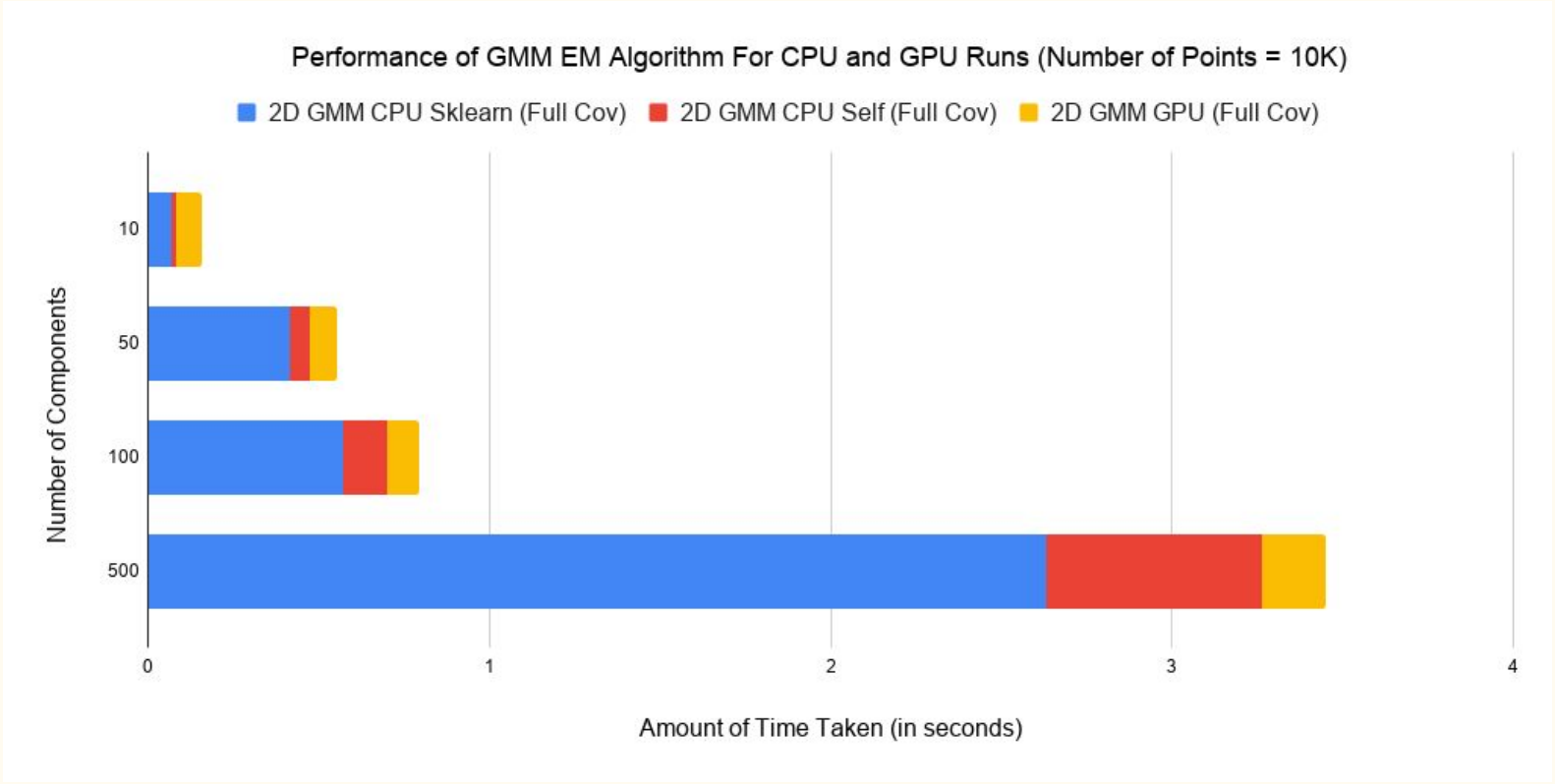
Performance Analysis

Performance Analysis: CPU vs GPU



Smaller is faster

Performance Analysis: CPU vs GPU



Smaller is faster

Current Issues:

- Point cloud registration using HGMM not working as expected.
- GMM sensitive to **hyperparameters: # of components vs # of points**
- GMM sensitive to initial conditions

Future RoadMap

1. Work Done So Far:
    a. GMM (different configurations) on GPU
    b. Point Cloud Registration with GMM
    c. 3D GMM Visualization on Live Waymo Dataset
    d. Real-Time Localization with GMM and H-GMM (CPU)
2. Milestone 4 (12/09) :
    a. Integrate Localization with GMM GPU
    b. Improve GPU speed with concurrency
    c. Complete HGMM on GPU
    d. Stretch Goal - Generate meshes on 3D Clouds with GMM