CIS 565 Final Project Proposal
GPU Accelerated Point Cloud Registration using Gaussian Mixture Models

Team Members: Srinath Rajagopalan, Dhruv Karthik and Somanshu Agarwal

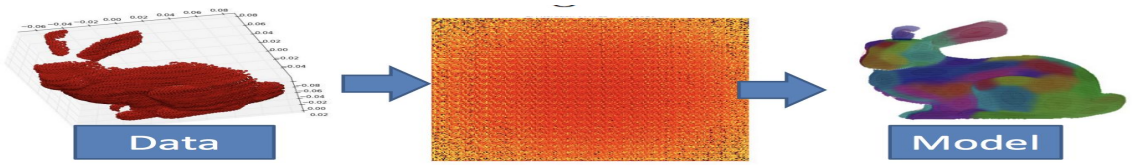
Reasons for switching from the old project:

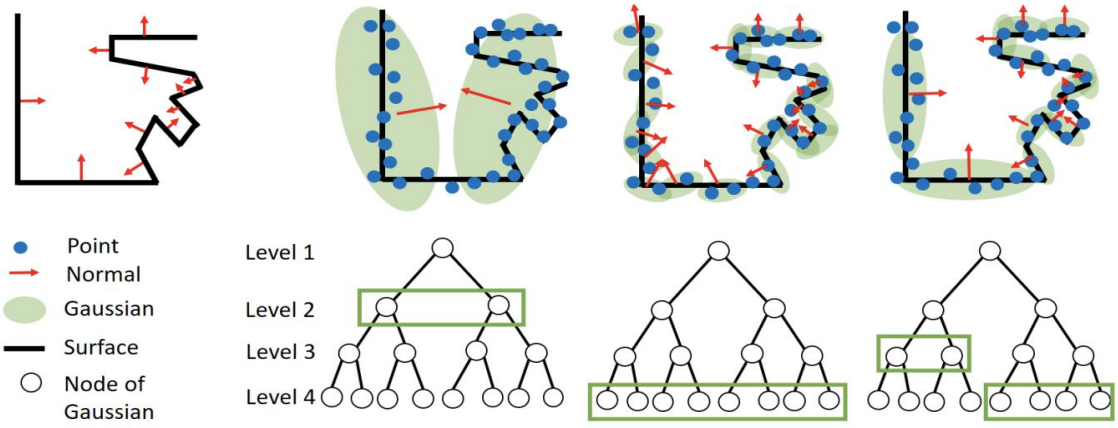
After pouring through the literature for visual odometry in the past week, we realized that the paper we originally planned to implement was an incremental improvement that may not benefit from GPU acceleration as much . There are many simpler algorithms for visual odometry from older papers which have already been implemented and our GPU programming contribution might be minimal. Also, being ML enthusiasts, it was a struggle to find something where we get to contribute on BOTH the GPU and ML fronts. Therefore we shifted focus to problems in the ML and 3D Point Cloud processing domains.

Overview:

Recently, researchers are exploring approaches to learn distributions on point clouds. This has the advantage of probabilistic sampling and a differential model. Last year, in ECCV 2018, Nvidia has proposed a GPU-Accelerated method to learn Hierarchical Gaussian Mixture Models. Though GMM-approaches for point cloud registration has been done before they don't scale well with model size, lack memory coherence, and each gaussian component requires access to the global memory. The proposed hierarchical approach can fit a sub-model entirely within the shared memory. The tree-based approaches also achieves logarithmic complexity in model size and scales efficiently to data with billions of point cloud.

$$\hat{\Theta} = \underset{\Theta}{\operatorname{argmax}}\, p(\mathcal{Z}|\Theta)$$





Why this?

- Though Nvidia released the paper, to our best knowledge, we could not find any implementation for it. We hope our implementation will be a contribution to the academic community.
- Implementing this will be a wonderful challenge in applying many of the GPU acceleration concepts we learnt in the course (shared memory, recursive tree data structures, memory coherence, parallel scans, CUDA streams,).
- Excited about implementing generative ML models on LIDAR Point Clouds. This project is a good confluence of ML and GPU concepts.
- This is a natural extension and advanced scale of our Project 4 (Scan Matching with ICP). So we have a comfortable background in the literature which we expect to help us catch up with some of the lost-time.

Milestones:

1. **11/18:** Understand GMM and HGMM registration for 3D Point Clouds. Get started with implementing a basic CPU version of GMM registration.
2. **11/25:** Complete GPU version of single model GMM registration. Prototype Python version for HGMM.
3. **11/02:** Complete GPU version of Hierarchical GMM with CUDA/C++. Test it on a Waymo's 3D LIDAR data. Benchmark with other implementations.
4. **11/09:** Implement additional optimizations (reduce bank conflicts). Test it on Dhruv's 3D LIDAR and deploy it for Real-Time PCR on Penn Campus.

References:

1. https://developer.download.nvidia.com/video/gputechconf/gtc/2019/presentation/s9623-gpu-accelerated-3d-point-cloud-processing-with-hierarchical-gaussian-mixtures.pdf
2. Fast and Accurate Point Cloud Registration using Trees of Gaussian Mixtures