Point Cloud Enhancement via Denoising/Dequantization of Measurements

Problem Statement

Depth maps obtained from ranging sensors are later converted to point clouds for visualization and interaction in 3d. However, depth maps obtained from ranging sensors comes with errors. Another source of error comes from the depth map being quantized, which is a required step for efficient transmission via lossless/lossy compression. Denoising of depth map can be a solution for this problem by with a proper noise model and regularization on spatial correlation, in a similar way as 2d image denoising. Point clouds also suffer from sparse measurements. It requires many samples to realize a smooth surface.

Project Description

For this project, I will investigate the model-based approaches for one or both of denoising and interpolation of 3d data. [1, 2] take model-based approaches to enhance point clouds by jointly performing denoising and linear interpolation using a pair of depth maps. [1] is interested in direct quantization in the depth, while [2] is interested in quantization from JPEG compression. [3,4,5] are example works on surface smoothing and interpolation. The goal of the project is to implement ideas that are mostly presented in [1,2] and validate its performance by comparing naïve projection followed by smoothing. If time allows, I am willing to explore beyond by attempting ways to combine the forward model and different regularizers inspired by smoothing algorithms that are found in these literatures. Forward models will need to be adjusted to my own setup since the devices presented in the literature are not in my possession. The assessment of the result is going to be mostly qualitative since representation of error is not as obvious as most of the 2d image enhancement problems.

Experiment Methods

I plan to collect both synthetic measurements and experimental measurements. Synthetic measurements can be collected from synthetically generating depth measurement on a 2d grid from smooth 3d surfaces (detailed mesh models) using library such as open3d. Synthetic noise will be added to depth maps and will undergo compression algorithms or a quantization scheme. Experimental measurements will be collected from lidar on my iPhone 12 Pro Max. Depth map of stationary objects will be captured from multiple angles. In this experiment, the approximate ground truth will be scanned 3d data over many more accumulated samples.

[1] X. Zhang, G. Cheung, J. Pang, Y. Sanghvi, Y., A. Gnanasambandam., & S.H. Chan. ” Graph-Based Depth Denoising & Dequantization for Point Cloud Enhancement,” *ArXiv, abs/2111.04946*, Oct. 2022.

[2] P. Wan, G. Cheung, P. A. Chou, D. Florencio, C. Zhang and O. C. Au, "Precision Enhancement of 3-D Surfaces from Compressed Multiview Depth Maps," in IEEE Signal Processing Letters, vol. 22, no. 10, pp. 1676-1680, Oct. 2015, doi: 10.1109/LSP.2015.2423372.

[3] M. Kazhdan, M. Bolitho, & H. Hoppe. (2006). ”Poisson Surface Reconstruction”. In *Symposium on Geometry Processing*. The Eurographics Association.

[4] W. Wan, "A novel suface reconstruction method for noisy point cloud," 2014 IEEE Workshop on Electronics, Computer and Applications, 2014, pp. 952-955, doi: 10.1109/IWECA.2014.6845779.

[5] S. Sellán, & A. Jacobson (2022). “Stochastic Poisson Surface Reconstruction”. *ACM Transactions on Graphics*.