Takeaways: Colored Point Cloud Registration Revisited

Abstract:

- Key idea is to optimize a joint photometric and geometric objective that locks the alignment along both the normal direction and the tangent plane.

Introduction:

- Problem Statement: Given two roughly aligned 3D point clouds, compute a tight alignment between them.
- Modern depth cameras commonly produce pairs of depth and color images. Softwares are there that associate color information with 3D scans.
- Considering color along with the geometry can increase the accuracy of point cloud registration.
- For integrating color into geometric registration algorithm the alignment is lifted into a higher-dimensional space, parameterized by both position and color.
- Correspondences are established in a four- or six-dimensional space rather than the physical three-dimensional space. These correspondences can pull away from the correct solution and prevent the method from establishing a maximally tight alignment.
- The approach of this paper is to establish correspondences in the physical 3D space, but define a joint optimization objective that integrates both geometric and photometric terms.
- To define a photometric objective for point cloud alignment, they introduce a virtual image on the tangent plane of every point, which provides local approximation to the implicit color variation.

RGB-D Image Alignment:

- In this section the authors have combined the photometric objective for RGB-D image alignment and the geometric objective defined on the same image plane.
- RGB-D image is composed of a color image I and a depth image D registered to same coordinate frame.
- [REFER PAPER] Photometric objective is formulated in terms of squared difference of intensities.

- [REFER PAPER] The correspondence is built by converting the depth pixel to a 3D point in the camera space, transforming it with T, and projecting it onto the image plane.
- We can define a geometric objective that compares the depth of pixels. Direct comparison between depth values leads to incorrect results since depth is measured in different camera spaces.
- It is important that the photometric objective and geometric objective are defined in the same parameterization domain.
- Change in parameterization domain enables generalization of these objective to unstructured point clouds.

Colored Point Cloud Registration:

- Parameterization:
    - The discrete function that retrieves the intensity of each point of the point cloud is to be generalized to a continuous function so that gradients can be computed.
    - A virtual orthogonal camera is introduced for each point, it is configured to observe point along the normal.
    - Image plane of the virtual camera is the tangent plane. It parameterizes a virtual image that can be represented as a continuous color function.
- Objective:
    - Refer the paper.
- Optimization:
    - They minimize the nonlinear least-squares objective using the Gauss-Newton method.
- Coarse-to-fine processing:
    - Objective function is non-convex and the optimization can get trapped into local minima.
    - Coarse-to-fine scheme is used to alleviate this problem.