Global Alignment of Meshes for the Microsoft HoloLens

Karen Hong[1], Kevin Shum[1], Jessica (Yi Fei) Bo[1], Martin Oswald[2], Pablo Speciale[2]

3D Vision[1], Computer Vision and Geometry Lab[2], ETH Zurich

1 Introduction

Goals & Objectives

- Implement a mesh registration algorithm based on the Guaranteed Outlier Removal (GORE) algorithm, developed by Bustos and Chin
- Refine GORE with ICP and RANSAC algorithms, compare performance

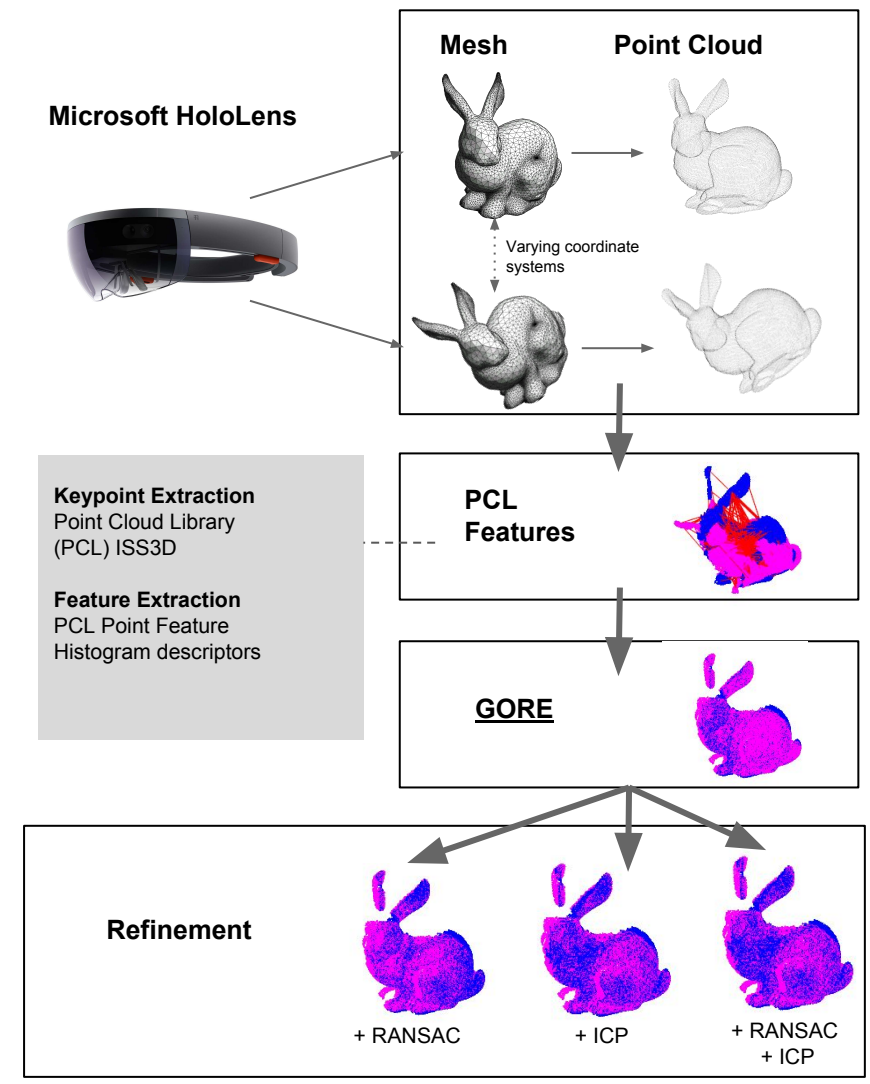
Challenges

- Meshes on different coordinate systems generated by the HoloLens are difficult to align accurately and consistently

Applications

- Stitching together different meshes taken at different points in time and aligning them into one global scene for VR and AR

2 Method Overview



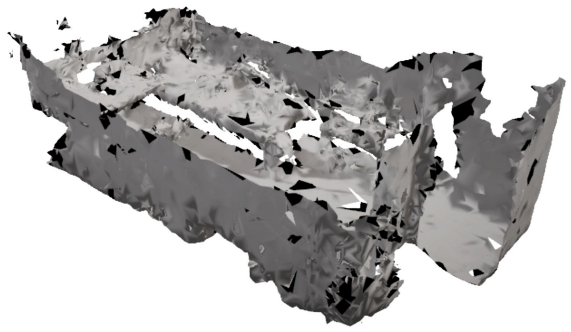


Fig. 2. HoloLens spatial map of a small indoor environment.

Input:
Independently generated spatial scans (meshes) created on the HoloLens with different coordinate systems (Fig.2)

Output:
Transformation matrix that aligns the two meshes into the same coordinate system

3 GORE Algorithm

- Given set of input points and correspondences, iterate over each point:
  1. Compute improved lower bound, l, and upper bound, $\hat{p}_k$
  2. Reject current point match as true outlier if the values of the bounds are not consistent
- GORE seeks to reject true outliers in set of points H and reduce to H', which is guaranteed to be included in the globally optimal solution I^*
- The maximum consensus problem is defined as:

$$\underset{\mathbf{T}\in SE(3),\ \mathcal{I}\subseteq\mathcal{H}}{\text{maximize}} \quad |\mathcal{I}|$$

subject to

$$\|\mathbf{R}\mathbf{x}_i + \mathbf{t} - \mathbf{y}_i\| \leq \xi,\ \forall i \in \mathcal{I}.$$

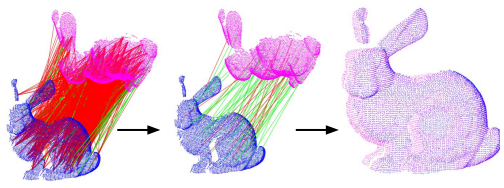


Fig. 3. GORE's alignment process (red are outliers, green are inliers).

4 Results and Discussion

Runtime

- GORE's runtime is the most deterministic (0.4s - 4s between datasets)
- RANSAC has low runtime & reduces ICP's runtime if performed prior to it

Angular Alignment Error

- ICP consistently improved angular errors for a point cloud in pure rotation, but results were not as consistent for a pure translation
- Normalized angular error between GORE, GORE+RANSAC, and GORE+RANSAC+ICP are similar at high rotation angles

Translation Alignment Error

- ICP improved translation errors for a point clouds in pure rotation, but the results worsened for a pure translation (instability observed in error)

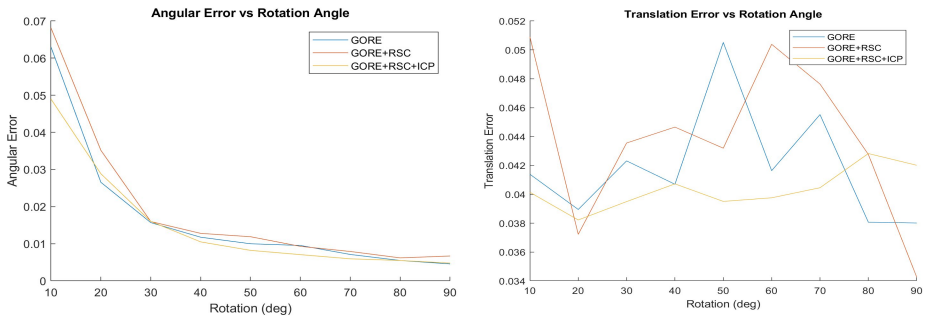


Fig. 4. Graphs of alignment errors at each rotation angle averaged over 10 unique point cloud datasets. Due to significantly higher error, ICP and GORE_ICP alignments were excluded.

5 Conclusion

- GORE is robust as a preprocessing step in removing true outliers from the search space, particularly when combined with refinement algorithms
- ICP refinement, in addition to GORE and RANSAC, reduces the angular error for aligning affinely transformed point clouds
- However, additional speedup is required for GORE to be more effective
- Prototype project shows potential for application to the HoloLens in C# for registering various meshes with different coordinate systems

6 References

1. Á. P. Bustos and T. J. Chin, "Guaranteed Outlier Removal for Rotation Search," 2015 IEEE International Conference on Computer Vision (ICCV), Santiago, 2015, pp. 2165-2173.
2. Radu B. Rusu et al. 3d is here: Point cloud library (pcl: pointclouds.org). In ICRA, 2011.
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