3D Point Cloud Registration
for the NYUSH IMA Telewindow Project

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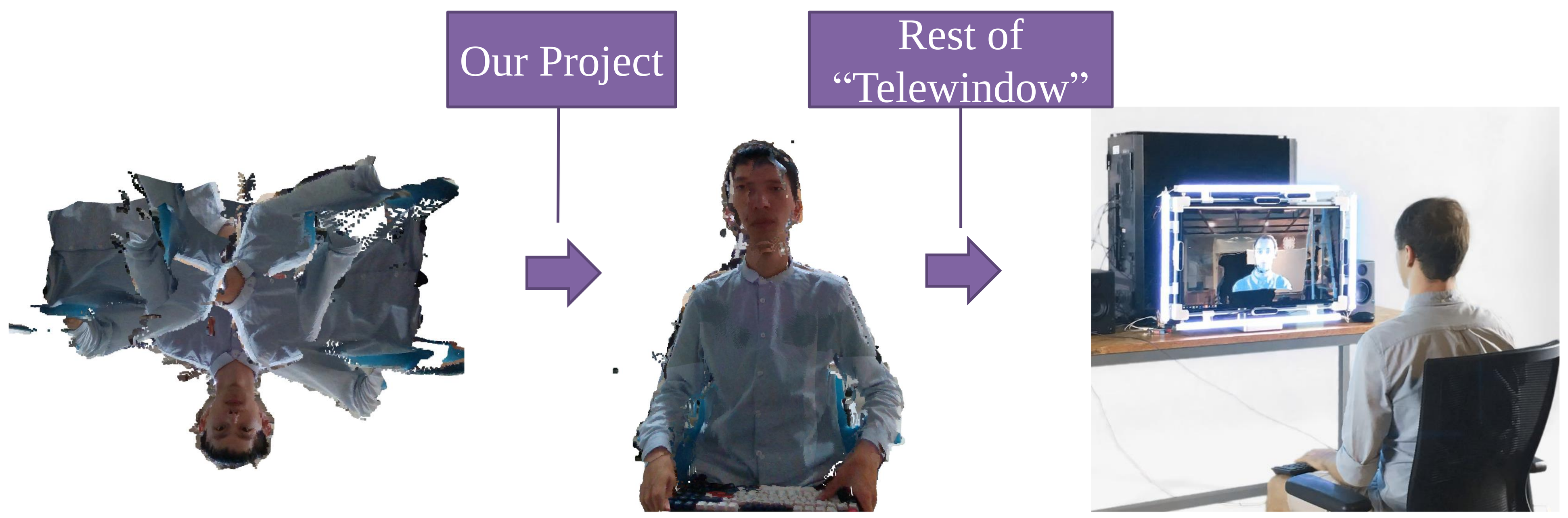
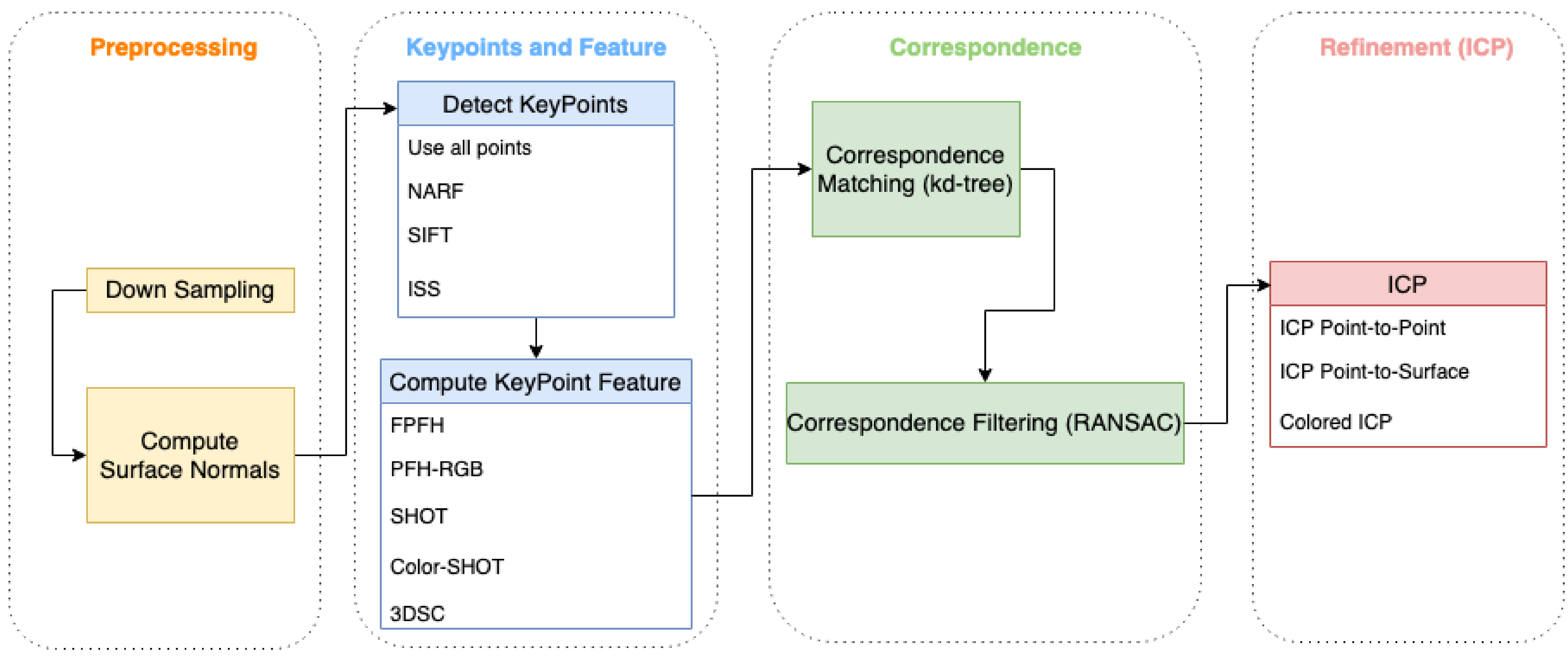
Introduction

This project is a part of the NYUSH IMA "Telewindow" project, whose goal is to enhance teleconferencing experience by providing 3D video streaming. Such 3D videos are produced by combining 3D point clouds captured by a set of depth cameras. The goal of this project is to develop a method that geometrically aligns, or "registers", these 3D point clouds into one 3D image. Current registration algorithms usually adopt a pipeline architecture with multiple stages. Plenty of variants are available for each stage and there is not a standardized solution suited for all applications. We build an experimental registration pipeline and investigate different combinations of the algorithms from each stage to find the optimal pipeline under the "Telewindow" project setting.



Solution

Current registration algorithms usually work by first extracting keypoints and computing their description (i.e. features), then performing feature-based correspondence estimation, and finally applying Iterative Closest Point algorithms (ICP) as fine-tuning. We build an experimental pipeline that ensembles multiple registration stages together. At each of the stages, we implement several candidate algorithms. The pipeline provides us with several different combinations of the algorithms from each registration stage that are ready to be tested.



Experiments and Results

We experimented on three typical scenes of teleconferencing to test our algorithms. Our registration pipeline is evaluated from two perspectives, running speed and accuracy. The accuracy is measured with Root Mean Squared Correspondence Error (RMSCE) and Maximum Correspondence Error (MCE). They represent the mean and the maximum matching error in terms of aligning the registered source clouds to the target cloud. The algorithms work best when the user is sitting up straight. Their performances degrade when the user is sitting sideways or holding objects. Overall, All Points + PFH/PFH-RGB + color-ICP is the optimal pipeline.

Sitting Up Straight

Methods	Time/s	RMSCE/m	MCE/m
All points+ FPFH+ color-ICP	8.80	0.015069	0.277851
All points+ PFH-RGB+ color-icp	11.14	0.015069	0.277851
All points+ SHOT+ color-icp	42.24	0.015069	0.277851

Sitting Sideways

Methods	Time/s	RMSCE/m	MCE/m
All points+ PFH-RGB+ Point-to-point	10.36	0.077370	0.444735
All points+ PFH-RGB+ color-icp	10.30	0.084194	0.444831
All points+ Color-SHOT+ color-icp	194.83	0.084194	0.444831

Holding Objects

Methods	Time/s	RMSCE/m	MCE/m
ISS+ PFH-RGB+ Point-to-point	4.40	0.089142	0.351056
All points+ SHOT+ color-icp	45.13	0.087861	0.348174
All points+ 3DSC+ Point-to-point	286.43	0.088057	0.373715

TABLES: Results of the three overall best combinations of algorithms for each scene.

FIGURES: The best registration results in terms of accuracy for each scene.

Conclusion

We build an experimental pipeline for 3D point cloud registration under the "Telewindow" project setting. We review classic algorithms for 3D registration and select the most potential ones for experiments. We investigate different combinations of algorithms in each registration stage by conducting experiments under different scenes with different users. Some promising pipelines are identified, which are able to finish the registration within 10 seconds and yield accurate registration results given clean enough point cloud data.

Future Works

We would like to explore the following directions in the future:

- Incorporate human facial keypoint detectors to obtain highly distinctive keypoints for registration.
- Use a calibration board to obtain accurate registration results that can be hard-coded into the machine. This will yield nearly perfect alignment yet requiring regular calibration.
- Experiment with adding point clouds from multiple consecutive frames to provide more data samples for feature detectors.

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