KNU
KYUNGPOOK NATIONAL UNIVERSITY
Computer & Robot Vision Lab.

Robust ICP Registration using Biunique Correspondence

Presented by:
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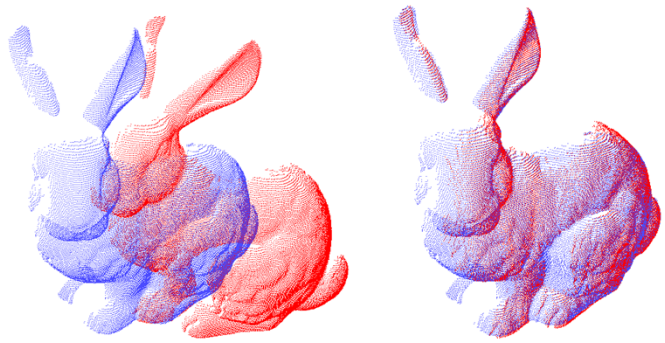
Introduction

- Range Image Registration:
  - Compute the rigid transformation that aligns two partially overlapping range images best.
- Iterative Closest Point (ICP)
  - One of the most popular methods for range image registration.
  - Classic "select-match-minimize" iterative process.
- Advantages:
  - Simplicity
  - Guarantee of convergence
- Disadvantages:
  - Easily trapped into a bad local minimum



Conventional ICP

- Two partially overlapping range images are given:
  - data set $P = \{p_i, i = 1, \cdots, N_P\}$
  - model set $M = \{m_j, j = 1, \cdots, N_M\}$

- The MSE object function is minimized:

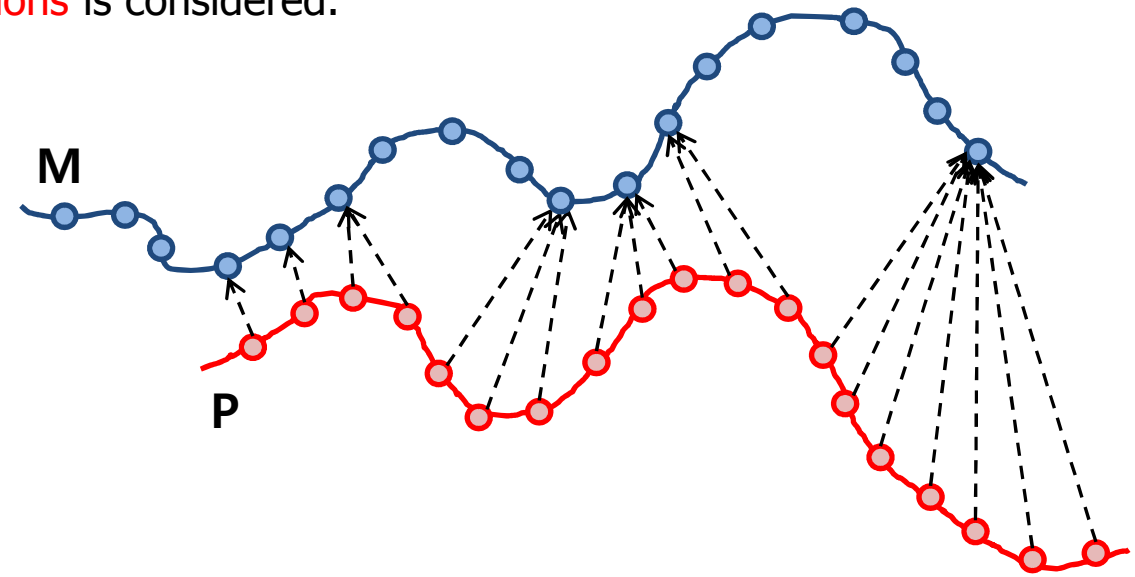
$$T = (R,t) = \arg\min_{(R,t)} \left\{ \sum_{i=1}^{n_p} \left\| m_j - Rp_i - t \right\|^2 \right\}$$

- Correspondences unknown:
  - Approximation: single closest point

Problem

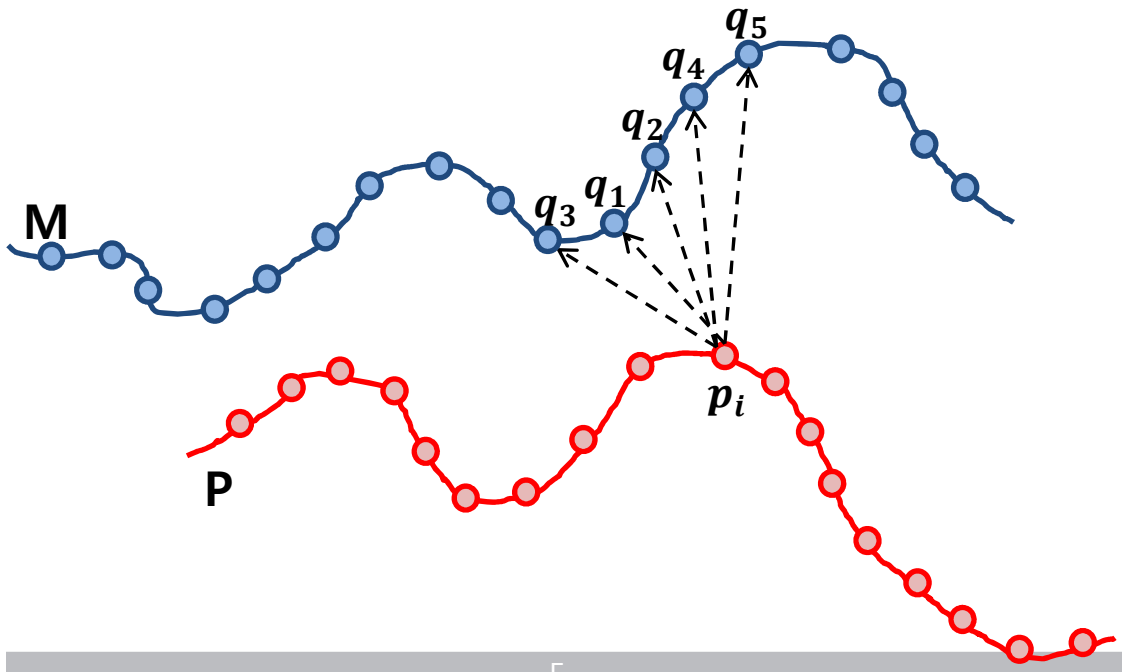
- Correspondences are concentrated on a few points in M.
  - Waste of information.
  - Difficult to distinguish between inliers and outliers.

- Uniqueness of correspondences:
  - Correspondences can be spread more uniformly if the uniqueness for both directions is considered.



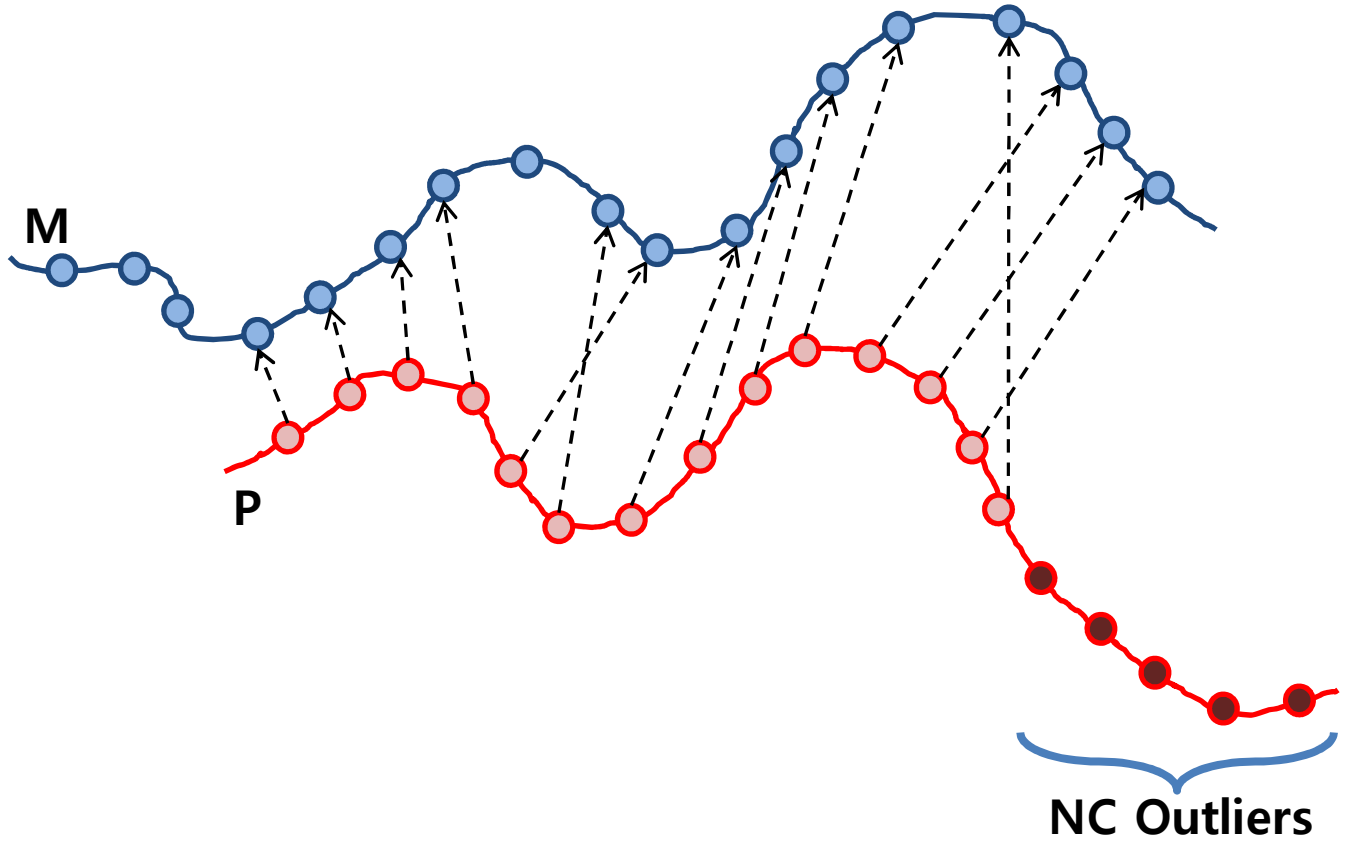
Multiple Closest Points Search (1)

- **Solution**:
  - Search multiple closest points for p_i, i.e. $q = \{q_k, k = 1, \cdots, 5\}$.
  - Sort $q = \{q_k, k = 1, \cdots, 5\}$ based on distance between p_i.
  - If possible, establish a biunique correspondence
  - If not possible, defined as No-Correspondence (NC) Outlier



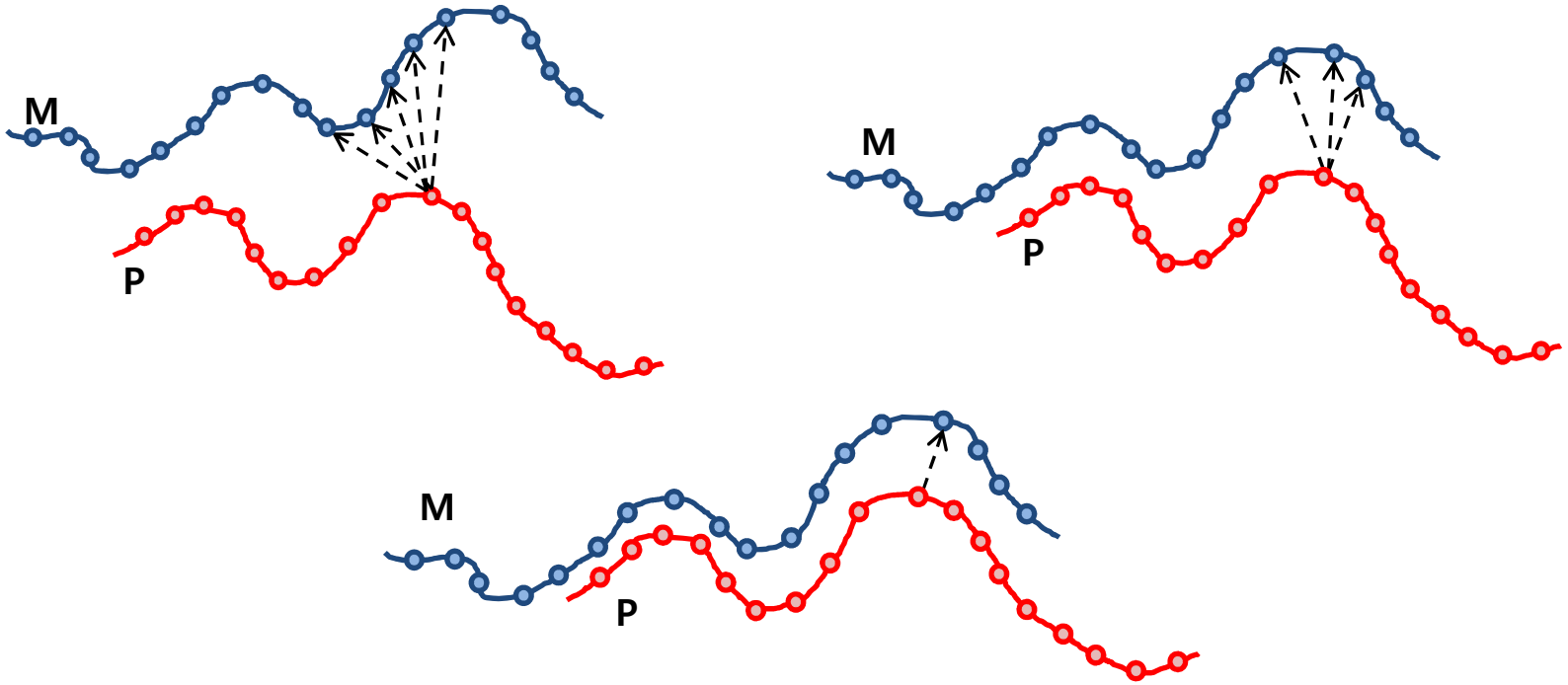
Multiple Closest Points Search (2)

- Examples for biunique correspondences and NC Outliers



Coarse-to-Fine Approach

- In early iterations, set $N_{M\,C}$ to a large number as coarse registration.
- As P and M are getting "closer", $N_{M\,C}$ is reduced step by step to create refinement.



Large Distance Outlier Rejection

- False matches still exit in biunique correspondences.
  - Correspondences with large distances should be rejected.

- Many researches have been conducted:
  - Static threshold
  - Statistical method [Zhang, 1994]
  - Trimmed ICP [Chetverikov, 2005]
  - Fractional ICP [Phillips, 2007]

- It is a good strategy that the computed threshold can cooperate with the coarse-to-fine approach.
  - We used the statistical method with a little modification

Experimental Results (1)

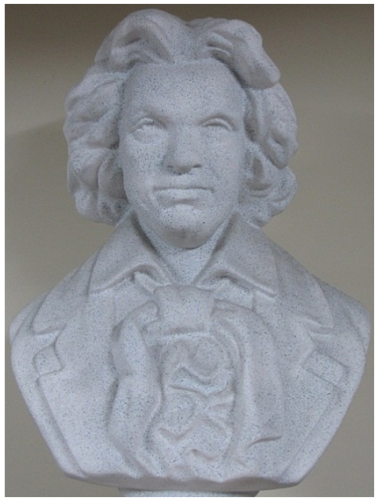
- We compared the proposed BC-ICP algorithm with the original ICP along with other variants:
  - Picky ICP: T.Zinsser and J.Schmidt, "A Refined ICP Algorithm for Robust 3-D Correspondence Estimation," ICIP, 2003
  - Fractional ICP: J. Phillips, R. Liu and C. Tomasi, "Outlier Robust ICP for Minimizing Fractional RMSD," 3DIM, 2007

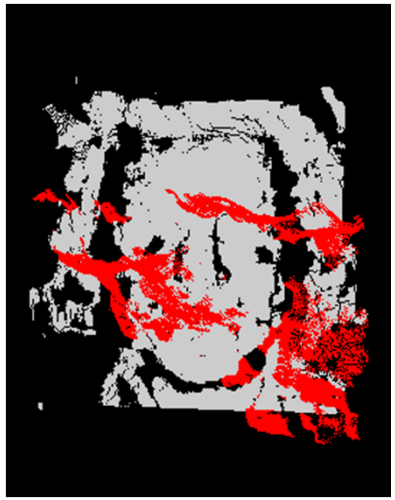
- Range images were captured from the Bumblebee 2 stereo-vision camera.

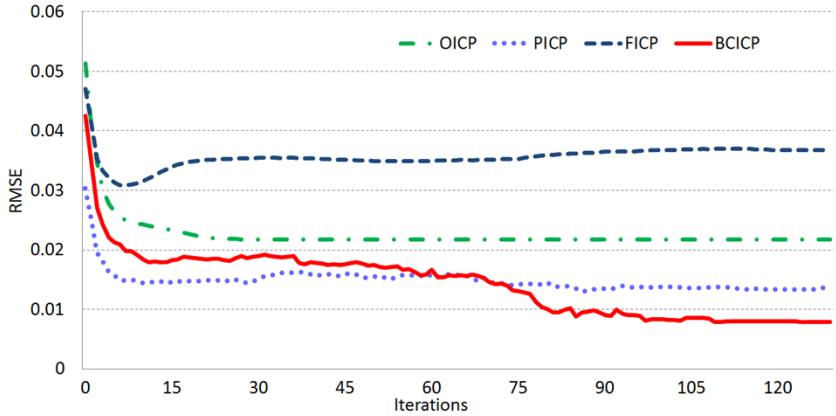
- Uniform sampling were used in all experiments.

Experimental Results (2)

- Pair-wise registration:

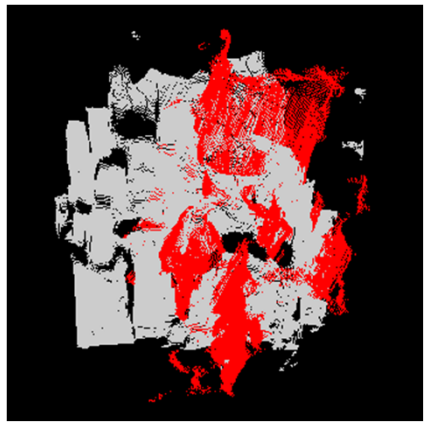


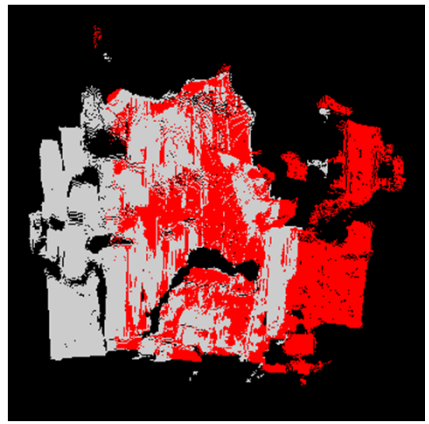


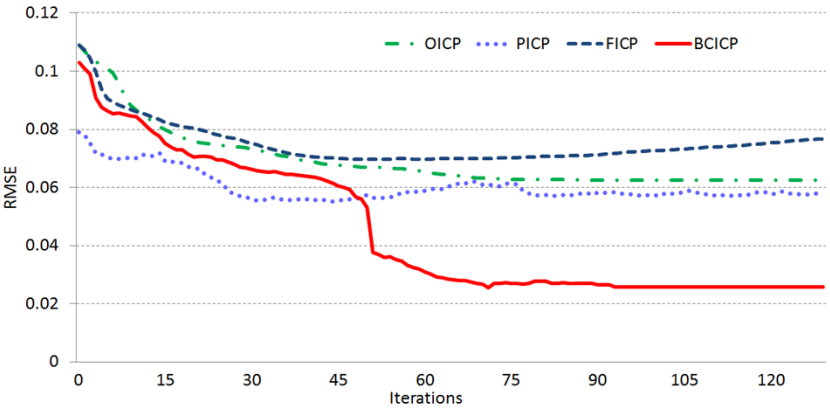


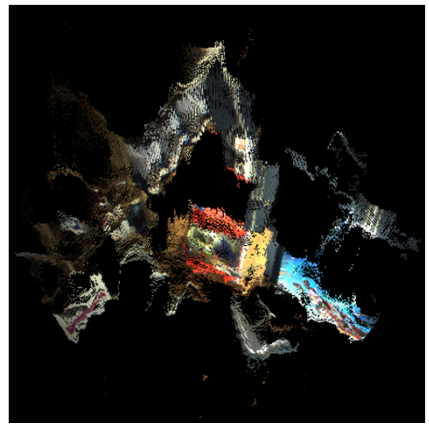
Experimental Results (3)

- Pair-wise registration



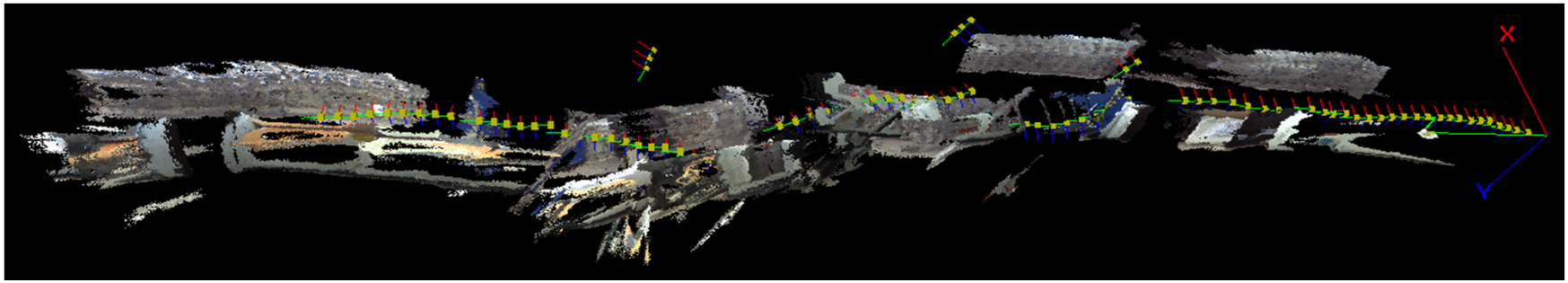






Experimental Results (4)

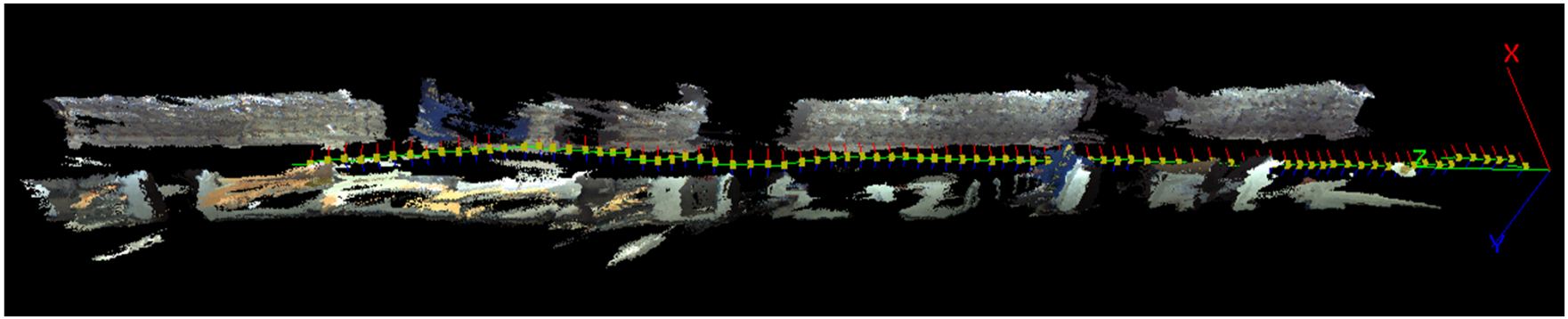
- 6DOF SLAM



Original ICP using wheel odometry as initial estimation

Experimental Results (5)

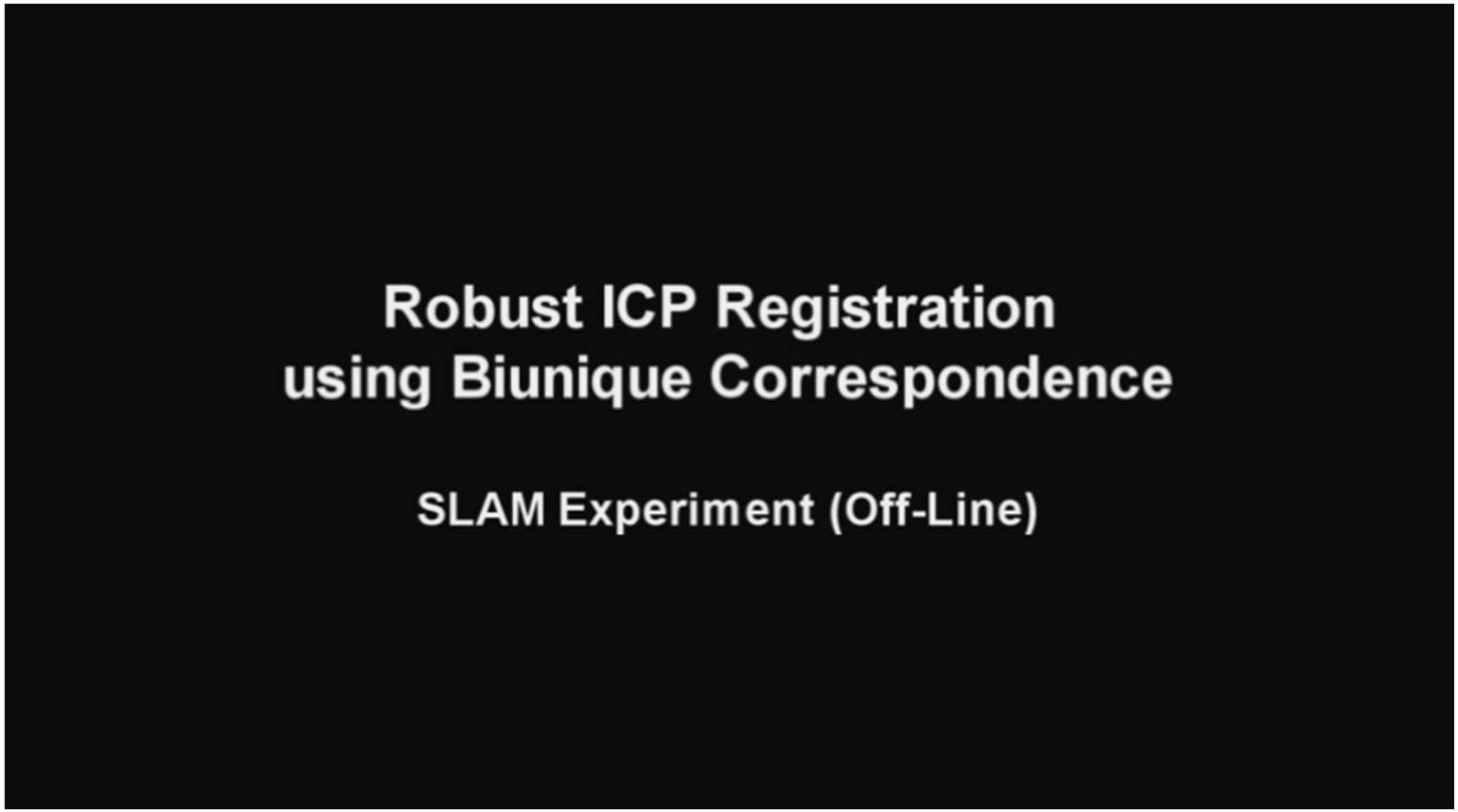
- 6DOF SLAM



BC-ICP using wheel odometry as initial estimation

Odometry	Algorithm	Aver. Time [ms]	Aver. # Iter.	Aver. RMSE	Std. Dev. RMSE
No	OICP	107.78	35.13	0.038	0.048
	BCICP	99.25	24.58	0.026	0.016
Yes	OICP	226.02	69.3	0.138	0.063
	BCICP	63.72	15.34	0.024	0.012

6DOF SLAM Demo video



Conclusions

- A novel variant of ICP algorithm, called Biunique Correspondence ICP, is proposed.
- We use multiple closest points search to ensure the uniqueness of correspondence in both direction.
- By discarding points that cannot assigned with a biunique correspondence, the robustness of ICP is greatly improved.
- A coarse-to-fine approach is adopted to maintain computational efficiency.
- Experiments show that BC-ICP is very robust against poor initial transformation and large non-overlapping area.

Thank You!