Fast Field-of-View Expansion for Collaborative Object Detection

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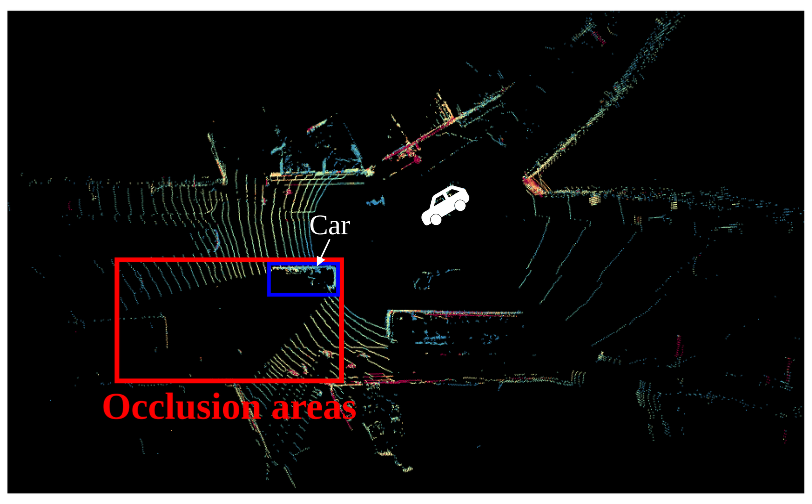
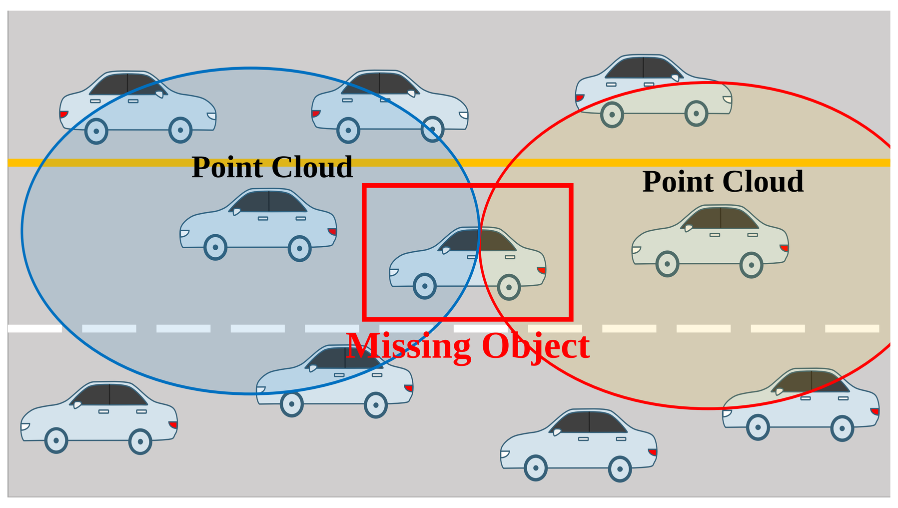
Introduction

Cooperative Object Detection

- **Detecting objects from a single vehicle** inevitably leads to the **creation of occlusion areas**.
- Proposing the transmission of only recognized objects has been one way to address this issue, yet this method **fails to detect objects at the boundaries of LiDAR's detection range**.
- **Registering multiple point clouds** and **recognizing objects** afterwards makes it **possible to detect previously unseen objects** at the boundaries, but existing technologies face **limitations in real-time processing**.

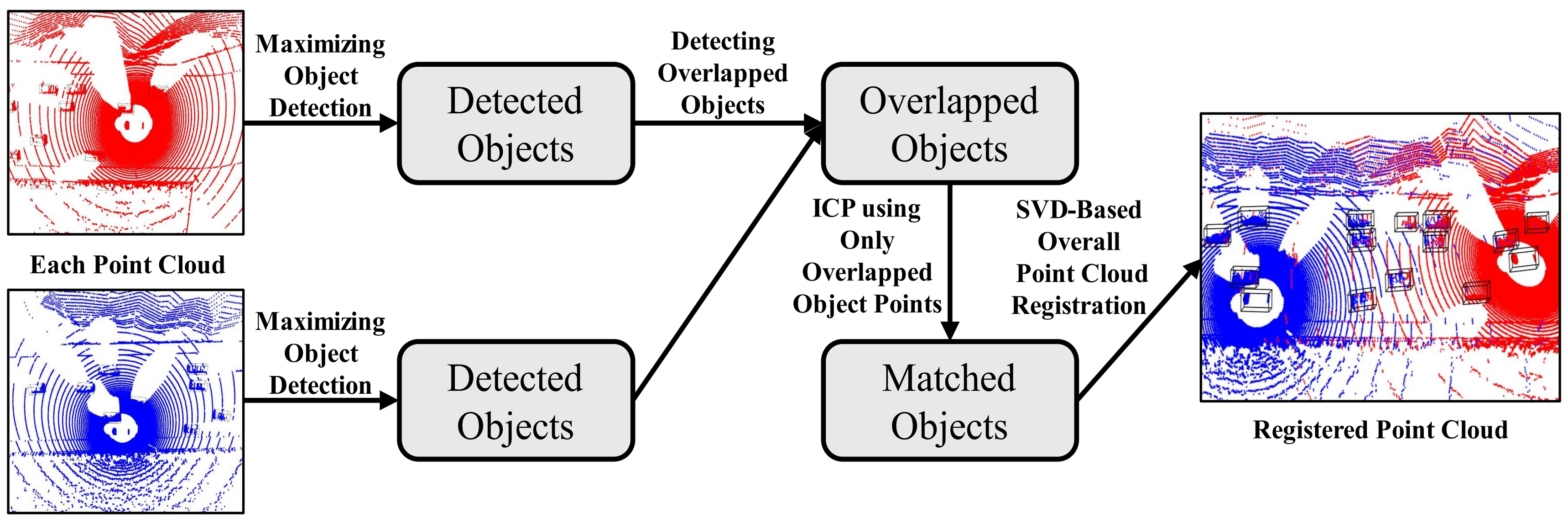
➔ **We propose fast registration methods using single points of objects through SP-ICP.**





Overall Flow

- ***Single-Point ICP includes the following step:***
  1) **Robust object recognition** in each vehicle.
  2) **Align initial positions** by combining recognized objects with GPS data.
  3) Conduct **SP-ICP** using **only overlapping objects**.
  4) Transmit the used **translation and rotation matrices**, along with the **entire point cloud**.
  5) **Register the remaining point cloud** using the **received translation and rotation matrices**.



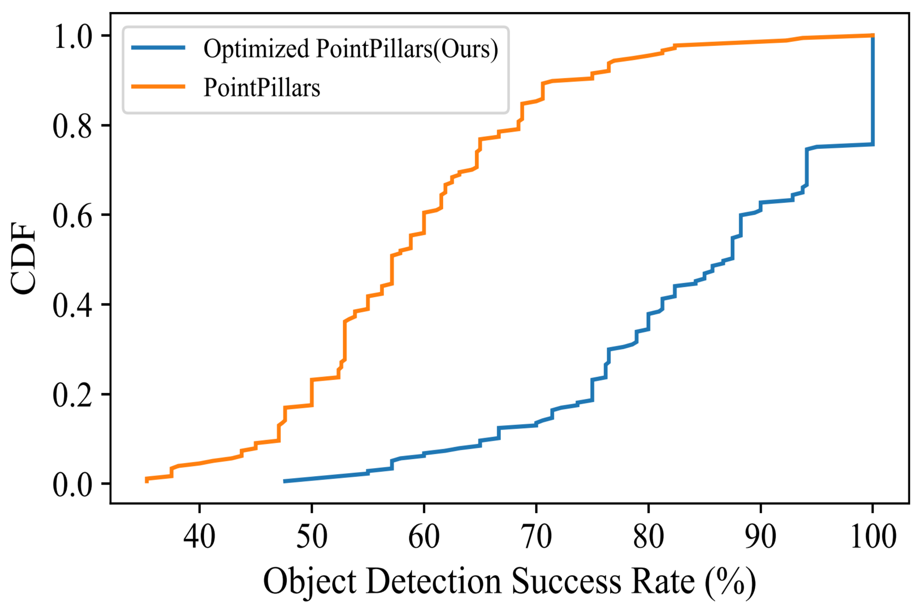
System Design

Robust Object Detection

- In **SP-ICP**, registration is performed using **only overlapping objects**.
- Preventing objects from being missed during recognition is more important than achieving accurate recognition.
- ***PointPillars*** had some objects missing in order to ensure accurate recognition.

➔ **Therefore, through parameter adjustments, it is ensured that as many objects as possible are detected, even if incorrect recognitions occur.**

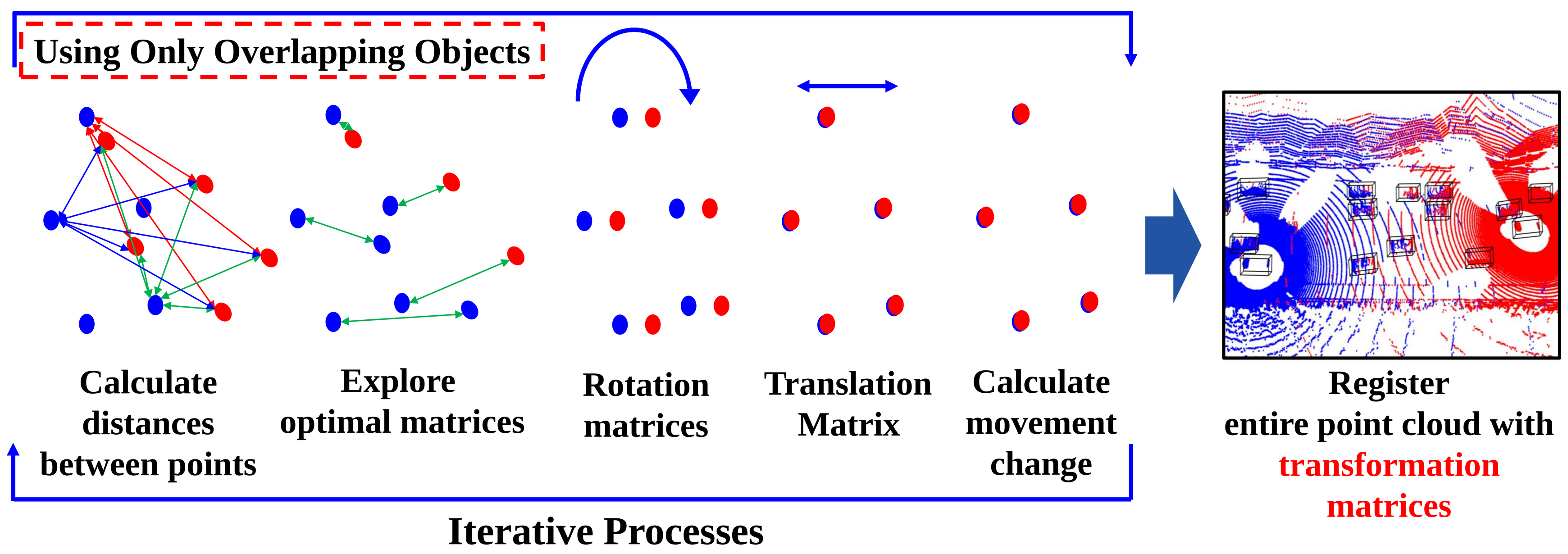
Focal Loss: $L_{cls} = -\alpha_a (1 - p^a)^\gamma \log p^a$, $\alpha = 0.3$, $\gamma = 3.0$, IoU = 0.4



- Enhancing the model's sensitivity, we adjusted various parameters and the proportion of overlap.
- **Probability of detecting objects** that were previously missed **increases.**

Single-Point ICP

- ***Minimized Object Points***
  - **Conventional ICP methods** consume significant computing power due to **iterative operations among countless points.**
  - **To minimize this**, translation and rotation matrices are determined **using single points centered on objects.**
- ***Registration Using Transformation Matrices***
  - Translation and rotation matrices, **derived from minimized points**, are utilized to register point clouds between vehicles.
  - Registration is efficiently achieved through **simple transformations using these matrices.**



Evaluation

Implementation

- We evaluated using OPV2V, a dataset that enables inter-vehicle communication.
- O-ICP has registered using data around objects over a wider range compared to SP-ICP.

Item \ Method	SP-ICP	O-ICP	ICP
Avg # of Points before Removal		57186.06	
Avg # of Reduced Points	24.71	797.16	17947.29
Avg # of Remained Points Ratio (%)	0.04	1.39	31.38
MAE (m)	0.37	0.63	3.65
mAP	0.84	0.71	0.28
Time (ms)	261.22	786.47	6043.85

Preliminary Results

- Registration was conducted using **only 0.04%** of the total points, achieving the **most accurate results** compared to other methods.
- Additionally, it demonstrated the **fastest performance** with a speed of **261.22ms.**

Future Work

- Modifications and testing will be carried out to enable real-time registration for more vehicles.
- We plan to conduct real experiments using actual LiDAR.