

# Introduction

## **Problem**

- Deep learning-based online extrinsic calibration methods such as [1] are now very accurate.
- However, none evaluates the uncertainty of its results.

### **Solution**

- First framework to estimate the associated uncertainty
- Combination of Monte Carlo Dropout [2] and Conformal Prediction [3].

# What is Extrinsic Calibration?



- Estimating the spatial relationships (rotation and translation) between sensors
- Ensures proper alignment for sensor fusion

# What is Uncertainty Estimation in This Context?

- Sources:
- model limitations (epistemic)
- o noise (aleatoric)
- Larger uncertainty signals less confidence
- **<u>Goal</u>**: obtaining intervals in which the truth is contained with at least a XX% probability (XX being a user-picked target)

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# Monte Carlo Dropout (MCD):

# **Conformal Prediction (CP):**

- varying uncertainty levels





[1] Mathieu Cocheteux et al. "MULi-Ev: Maintaining Unperturbed LiDAR-Event Calibration." Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, IEEE/CVF, 2024. [2] Yarin Gal and Zoubin Ghahramani. "Dropout as a bayesian approximation: Representing model uncertainty in deep learning." International Conference on Machine Learning (ICML), PMLR, 2016. [3] Vladimir Vovk et al. "Algorithmic learning in a random world." Springer Science, 2005.



Results					
KITTI test for 95% intervals					
X	Y	Z	Roll	Pitch	Yaw
5.3%	94.3%	94%	93.7%	94.5%	94.9%
62 <i>cm</i>	2.14 <i>cm</i>	3.10 <i>cm</i>	0.17°	0.39°	0.19°
ble intervals with desired level of confidence is insights on calibration quality st through improved explainability					
d Truth tion	(10) = 99% $(5) = 90%$ $(5) = -5$ $(5) =$	Interval Interval Interval Ground T Prediction	Fruth $10 - 5 - 5 - 10$ (IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	<ul> <li>99% Interval</li> <li>95% Interval</li> <li>90% Interval</li> <li>90% Interval</li> </ul>	Ground Truth Prediction
d Truth tion	$\begin{array}{c} 1.0 \\ 0.5 \\ 0.5 \\ 0.0 \\ -0.5 \\ -1.0 \end{array}$	5 Interval 5 Interval 6 Interval 7 Frediction	$\begin{array}{c} 1.0 \\ 0.5 \\ 0.5 \\ \hline \\ 0.0 \\ 1 \\ -0.5 \\ -1.0 $	99% Interval 95% Interval 90% Interval	Free service of the s