KI DATA TOOLING
The Data Kit for Automotive AI

# Sensor Equivariance

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ML Function Development


## Abstract

For scalable and robust perception systems in autonomous vehicles, it must be ensured that the perception algorithms are functional independently of the sensor model used during training and inference. The global objective is to reduce the development costs for new systems and to enable flexible and simple adaptation to new sensor models.


## Motivation

- High costs and effort for the development, construction, annotation and recording of real data
- Dedicated engineering and AI development leads to its bias to the sensor system used
- When adapting to a new sensor system, the development starts from scratch, relying on new data

## Concept: Sensor Equivariance

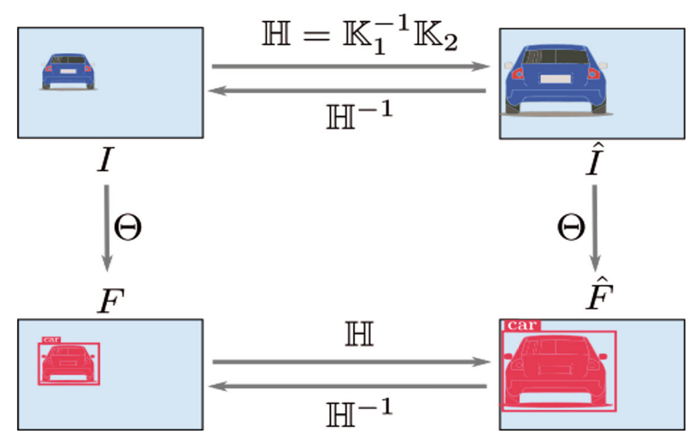


*Fig.1: Concept of sensor equivariance. Objects can be represented differently in sensors regarding sensor intrinsic and distance to the object. Feature extractors or neural networks Θ should extract comparable features,regardless of the sensor used (left). (© TH Aschaffenburg).*

- Building neural networks that work with different sensors (e. g. different cameras) is a challenging generalization problem
- Distortions and ambiguities pose a particular challenge in this respect
- A way to aid neural networks in these tasks is needed

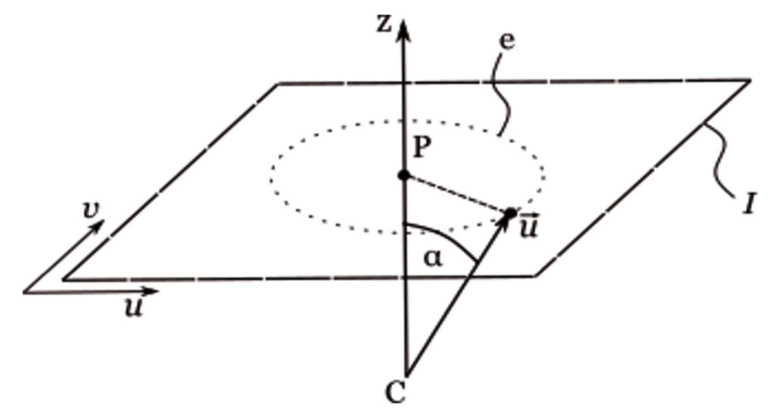


*Fig.2: Deflection metric. A way to encode sensor properties to an image representation (© TH Aschaffenburg).*

By encoding a deflection angle □ to each pixel (u,v) (see Fig 2.) the scale arbitrarity is resolved [1,2], allowing neural networks to learn scale equivariant features from data.

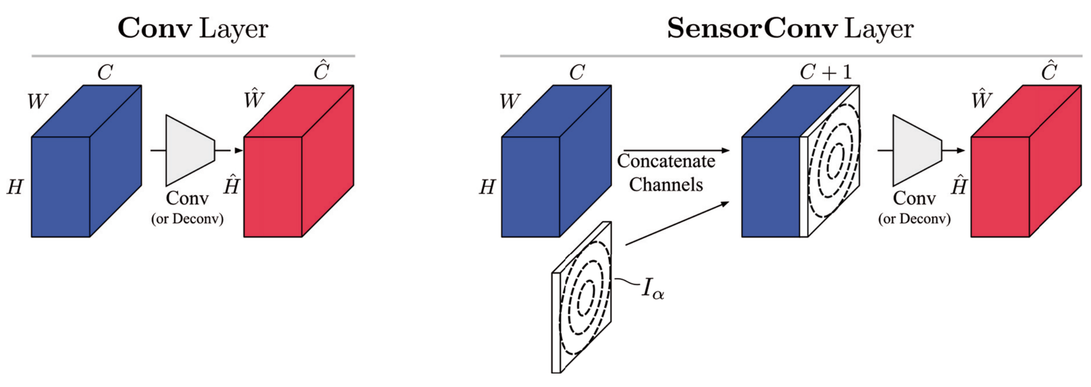


*Fig.3: SensorConv layer. With our proposed SensorConv layer, neural networks can utilize sensor properties to extract features (© TH Aschaffenburg).*

With SensorConvs (see Fig. 3) we propose an extension to convolution operations that can take sensor properties into account. Together with a strong data augmentation pipeline (see Fig. 4), various sensor models can be proposed to a neural network during training and evaluation.

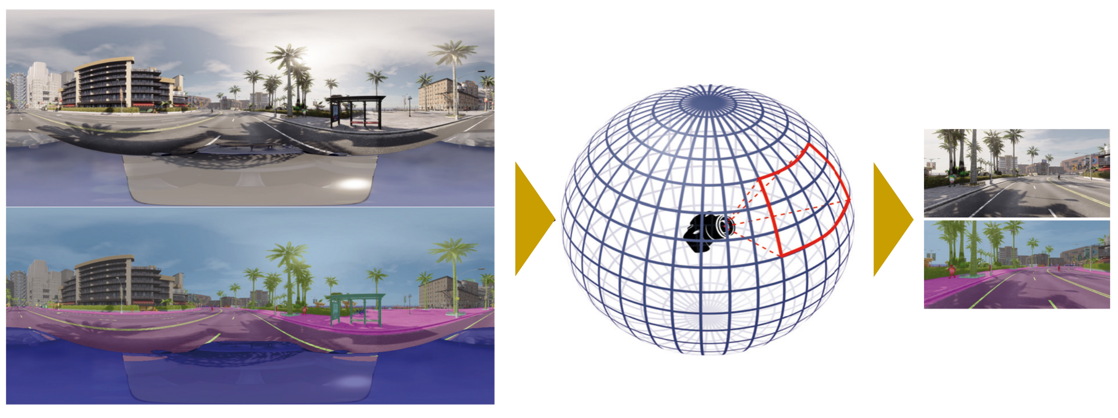

*Fig.4: Augmentation Pipeline (© TH Aschaffenburg).*

- Equirectangular cameras serve as a sensor baseline
- From equirectangular images various camera sensors can be emulated (pinhole, wide angle, fish eye ...)
- We use the CARLA simulator to create a dataset

## Application: Semantic Segmentation [3]

- We evaluate our method against various baselines at data from various emulated sensors (differences in field of view, resolution, aspect ratios)
- We can show that sensor bias is avoided and that our approach generalizes better

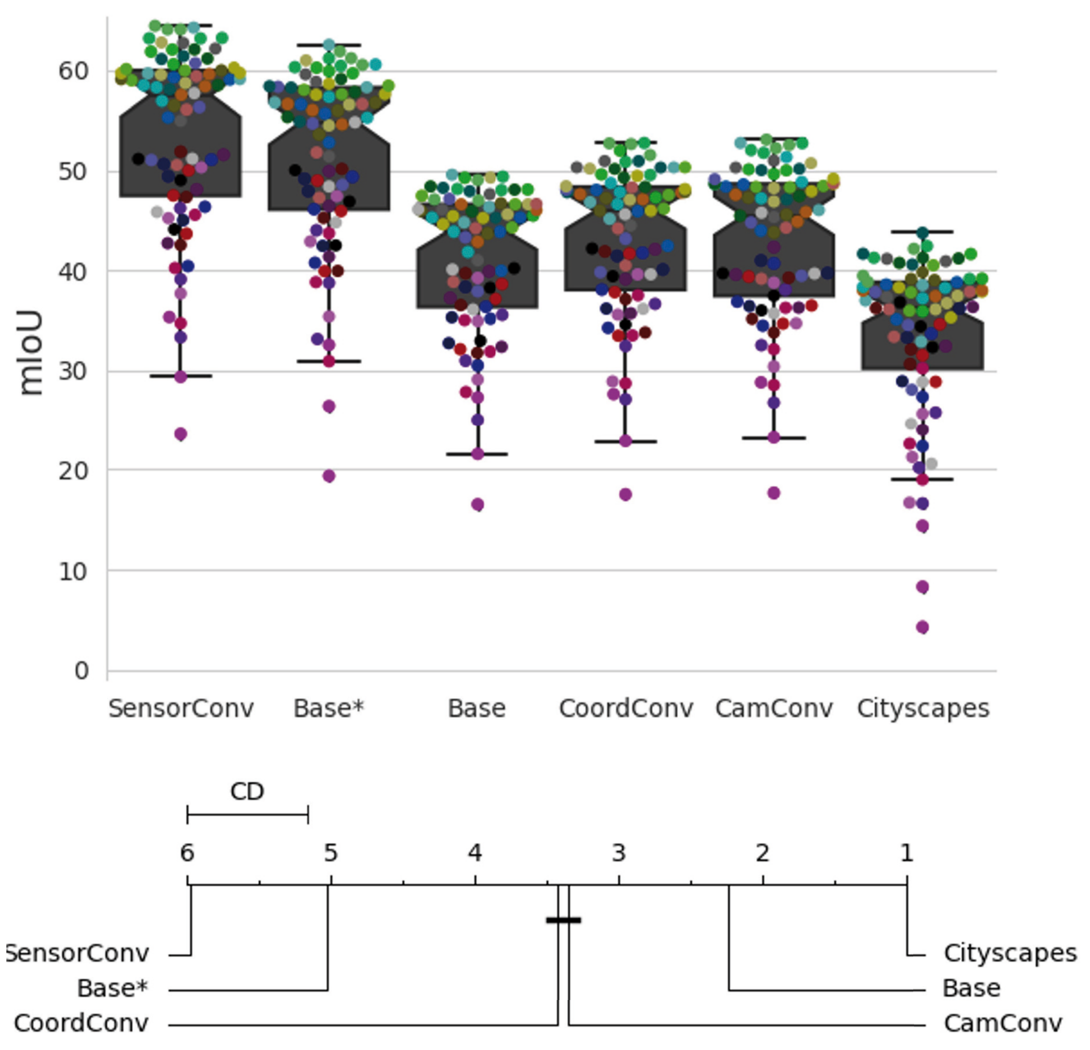


*Fig.5: mIoU compared among various models as box plots (top) and statistical significance test (bottom) (© TH Aschaffenburg).*

## Publications


[1] H. Reichert and K. Doll. (2022). An image encoding method for recording projection information of two-dimensional projections (WO2023118163A1). WIPO (PCT).

[2] H. Reichert, M. Hetzel, S. Schreck, K. Doll and B. Sick, "Sensor Equivariance by LiDAR Projection Images," 2023 IEEE Intelligent Vehicles Symposium (IV), Anchorage, AK, USA, 2023, pp. 1-6, doi: 10.1109/IV55152.2023.10186817.

[3] H. Reichert, M. Hetzel, A. Hubert, K. Doll and B. Sick, "Sensor Equivariance: A Framework for Semantic Segmentation with Diverse Camera Models," 2024 CVF CVPR, Seattle USA (submitted)


## Partners

## External partners

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