Guiding Attention in End-to-End Driving Models

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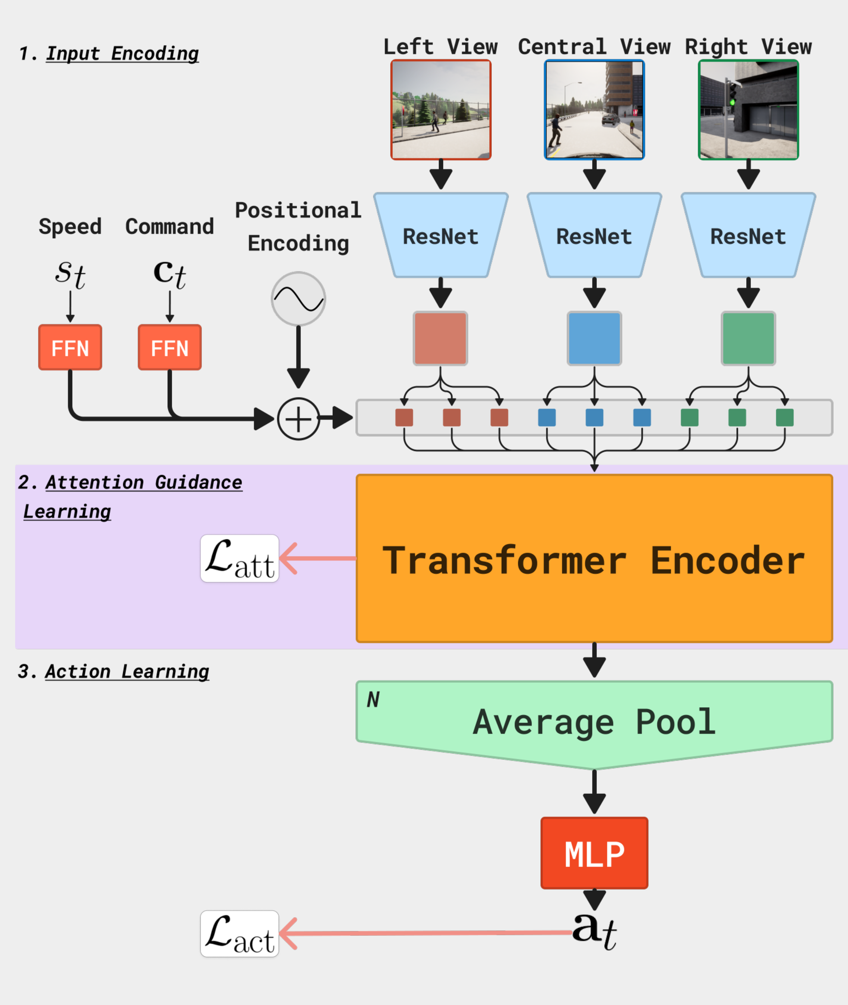
Website Paper Code

Problem Formulation & Motivation

With Imitation Learning (IL), driving policies seek to **approximate the driving behavior of the expert driver** that collects the training data. Vision-based end-to-end driving trained via IL offer **affordable solutions** for autonomous driving, albeit they require **large amounts of data** in order to properly converge.

In this paper, we study the effects of **directly optimizing the attention maps** on the driving capabilities of these models and their interpretability. We show that the model's **sample efficiency improves**, highlighted when there is a low amount of data to train with.

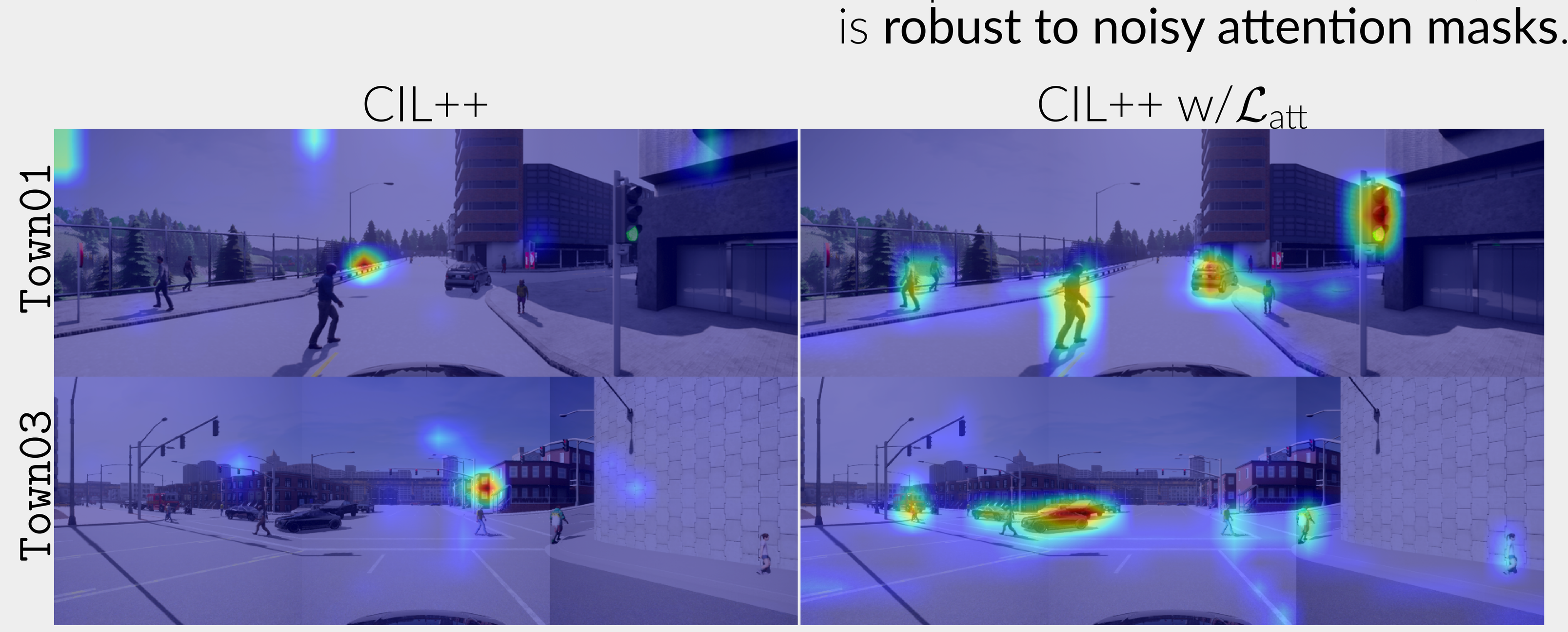
What if we directly optimize the self-attention weights?



We base our work on the current pure vision-based state-of-the-art end-to-end driving model **CIL++**.

Benefits

- Adding the Attention Loss $\mathcal{L}_{att}$ during training **circumvents the need to predict the attention masks during validation**, nor to modify the original architecture.
- The model's interpretability is improved, as the **attention weights now weakly segment the classes of interest** (pedestrian, vehicles, traffic lights, lane lines, and curb).
- The model also **needs less data** to get the same driving quality compared to the vanilla CIL++, and is **robust to noisy attention masks**.



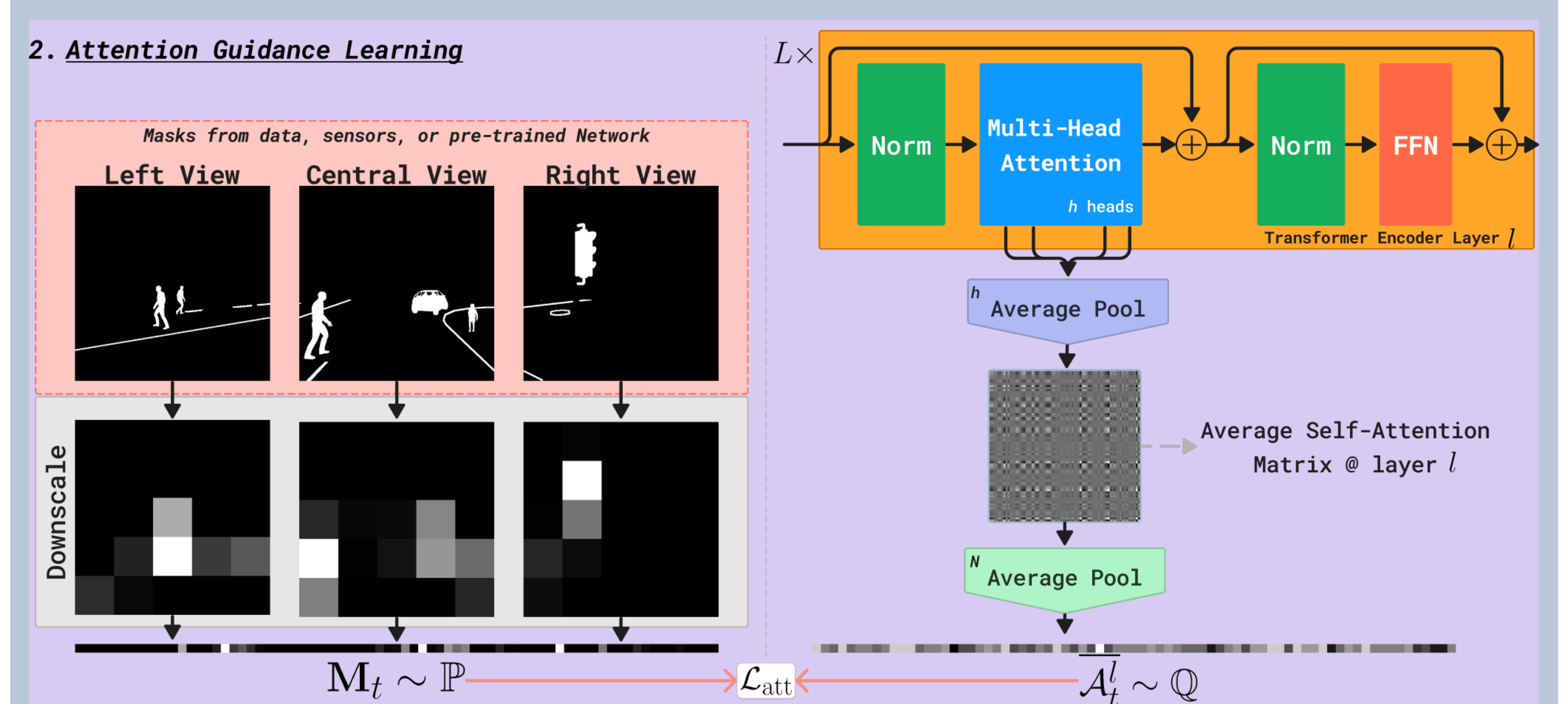
Future Work

$\mathcal{L}_{att}$ could be applied not only to the average attention weight of a layer in the Transformer Encoder, but to their **individual heads**. Likewise, the attention masks could also come from **human saliency maps** collected during driving.

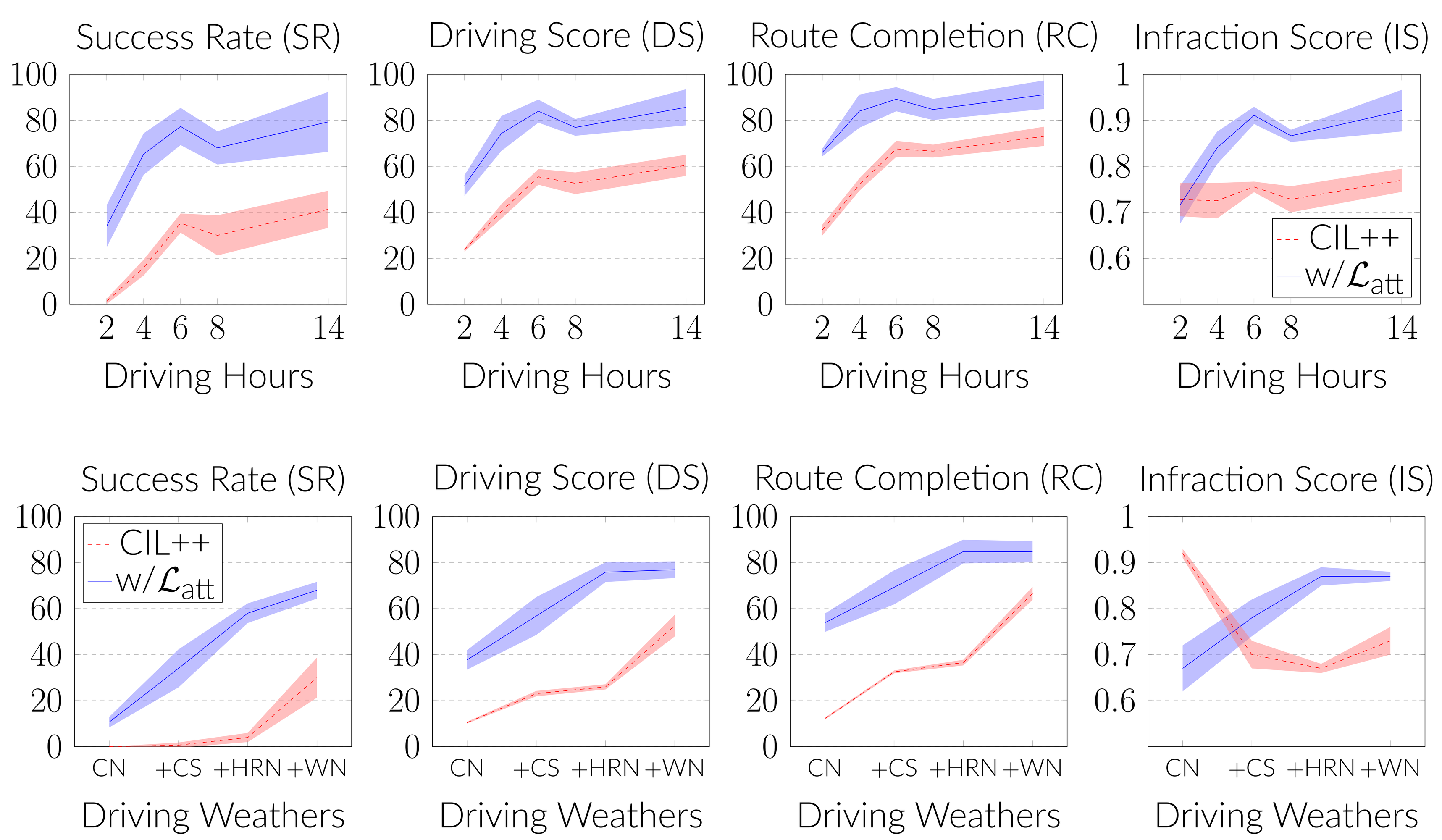
Our proposal: the Attention Loss $\mathcal{L}_{att}$

We wish to exploit the **distributional property** of the attention weights of the Transformer Encoder. For this, we create ground-truth single-channel *synthetic* attention masks $\mathcal{M}_{i,t}$ for each camera i based on Semantic Segmentation images (containing the classes of interest), filtered within a depth threshold.

We define the **Attention Loss** $\mathcal{L}_{att}$ as the KL Divergence between the (downscaled, concatenated, and normalized) ground-truth saliency maps $\mathbf{M}_t$ and the average attention weights of layer l of the Transformer Encoder $\overline{\mathcal{A}}_t^l$ at time t.



~ 4× less training data for the same driving capability!



$\mathcal{L}_{att}$ is robust to noisy saliency masks

Obtaining the *synthetic attention* masks for real-world data will result in **noisy masks**. We mimic this noise via a function f that corrupts the mask $\mathcal{M}_{i,t}$ using depth-aware Perlin noise, with more granular disturbances on larger objects. As a proxy, we train a UNet to predict the mask $\widehat{\mathcal{M}}_{i,t}$ given an input image $\mathbf{x}_{i,t}$.

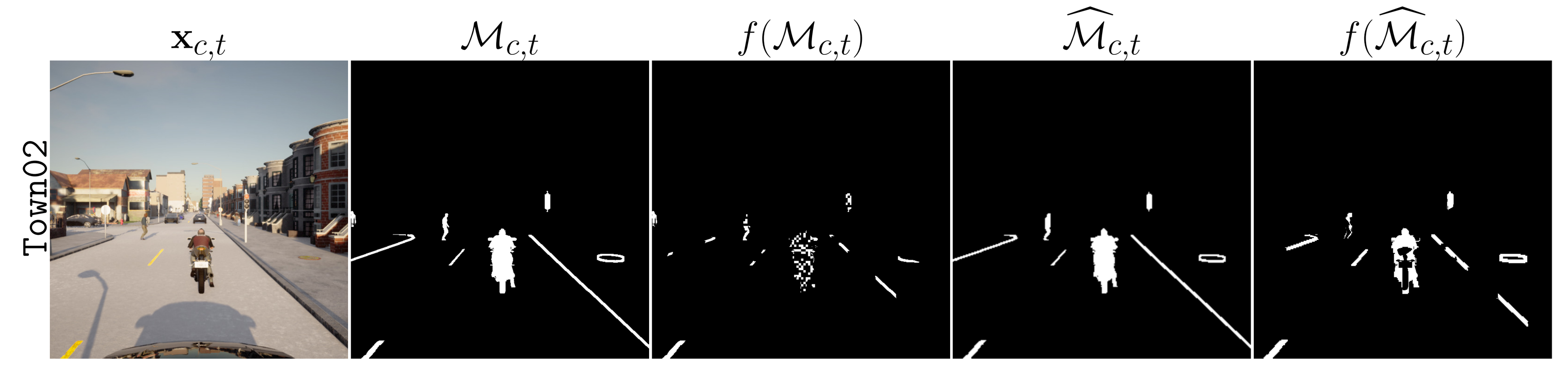


Table 1. Masks as different types of input and effect of noisy masks. Models trained with 14 hours of data from `Town01` and tested in `Town02`, using new weathers.

	SR ↑	DS ↑	RC ↑	IS ↑
CIL++	41.33 ± 8.08	60.45 ± 4.60	73.03 ± 4.18	0.77 ± 0.03
w/SM	42.00 ± 7.21	59.29 ± 5.49	70.12 ± 4.32	0.78 ± 0.02
w/HM	66.00 ± 9.17	77.34 ± 6.93	84.32 ± 5.83	0.87 ± 0.04
w/$\mathcal{L}_{att}$	$\mathbf{79.33} \pm 13.01$	$\mathbf{85.67} \pm 7.84$	$\mathbf{91.13} \pm 6.21$	$\mathbf{0.92} \pm 0.05$
w/SM + $f(\widehat{\mathcal{M}}_{i,t})$ [a]	35.33 ± 7.02	56.38 ± 1.32	68.38 ± 0.58	0.77 ± 0.01
w/HM + $f(\widehat{\mathcal{M}}_{i,t})$	66.00 ± 7.21	76.36 ± 3.72	83.46 ± 4.48	0.87 ± 0.01
w/$\mathcal{L}_{att}$ + $f(\mathcal{M}_{i,t})$ [b]	$\mathbf{71.33} \pm 6.11$	$\mathbf{80.36} \pm 6.88$	$\mathbf{89.46} \pm 3.97$	$\mathbf{0.87} \pm 0.05$

[a] Noisy predicted Masks (Training + Validation) [b] Noisy Masks (Training only)

Table 2. Effect of using $\mathcal{L}_{att}$ in the high-data regime for multi-lane towns in CARLA. Models trained with 55 hours of driving data and tested in the unseen `Town05`, using new weathers.

	SR ↑	DS ↑	RC ↑	IS ↑
CIL++	70.00 ± 5.00	36.46 ± 4.03	79.69 ± 3.84	0.51 ± 0.04
w/$\mathcal{L}_{att}$	$\mathbf{73.33} \pm 5.77$	$\mathbf{58.23} \pm 4.71$	$\mathbf{82.88} \pm 1.28$	$\mathbf{0.70} \pm 0.03$

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