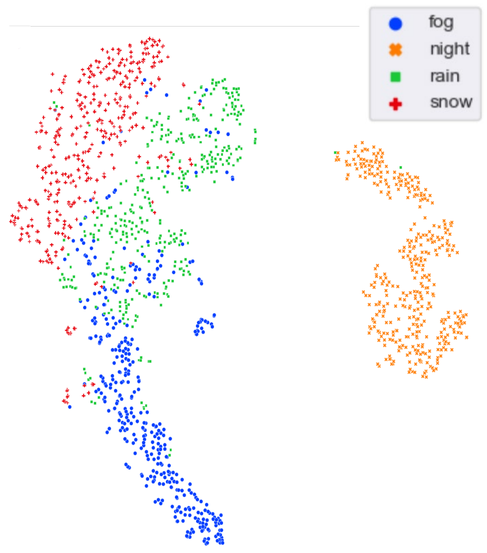
A Subdomain-Specific Knowledge Distillation for Unsupervised Domain Adaptation in Adverse Weather Conditions

Gyuwon Choi*, Yejin Lee*, Donggon Jang, Dae-Shik Kim
{gyuwonchoi, yejin}@kaist.ac.kr
Korea Advanced Institute of Science and Technology

Motivation

Unsupervised Domain Adaptation for Semantic Segmentation in Adverse Weather Condition

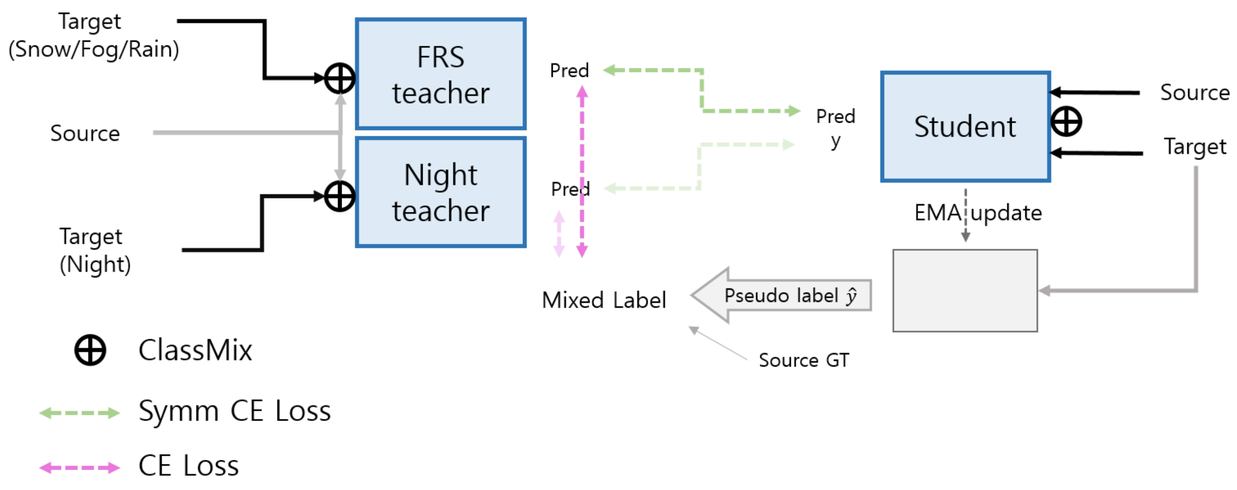
- Semantic segmentation models suffer performance degradation due to large domain gap in weather, season, and brightness.
- We demonstrates that there is a significant distribution gap between the fog, rain, and snow (FRS) and night in the ACDC dataset by visualizing the dataset's style statistics using t-SNE.
- Existing Cityscapes → ACDC domain adaptation methods have assumed target domain as a single distribution even if there is a large gap between FRS and night.



Method

Overview

- The architecture consists of two subdomain teachers, a student and exponential moving average model of student.
- We perform self-training on each subdomain and distill each teachers' knowledge to the student with symmetric cross-entropy.
- With EMA student, we can accumulate specialized knowledge for each subdomain and obtain less noisy pseudo labels for self-training.



Subdomain-specialized teacher

- We train the domain-specialized teachers, assuming that fog, rain, and snow (FRS) and night are different distributions.
- The teacher model is trained using only images from each subdomain as input, and it is learned through a cross-entropy loss between its predictions and pseudo labels.
- To reduce the large gap between source and target, we augment source and target images using ClassMix.
- To extract domain-specific knowledge to each teacher, source samples are matched to the target style using histogram matching.

Online Knowledge Distillation

- We perform online knowledge distillation by distributing each batch to consolidate each teacher's information into a student.
- Symmetric cross-entropy loss prevents rapid gradient change due to overconfident predictions and stabilizes the optimization process.

$$\mathcal{L} = -\alpha \sum_{h=1}^{H}\sum_{w=1}^{W}\sum_{c=1}^{C} p_{tch}(x)\log p_{stu}(x) - \beta \sum_{h=1}^{H}\sum_{w=1}^{W}\sum_{c=1}^{C} p_{stu}(x)\log p_{tch}(x)$$

Experiments

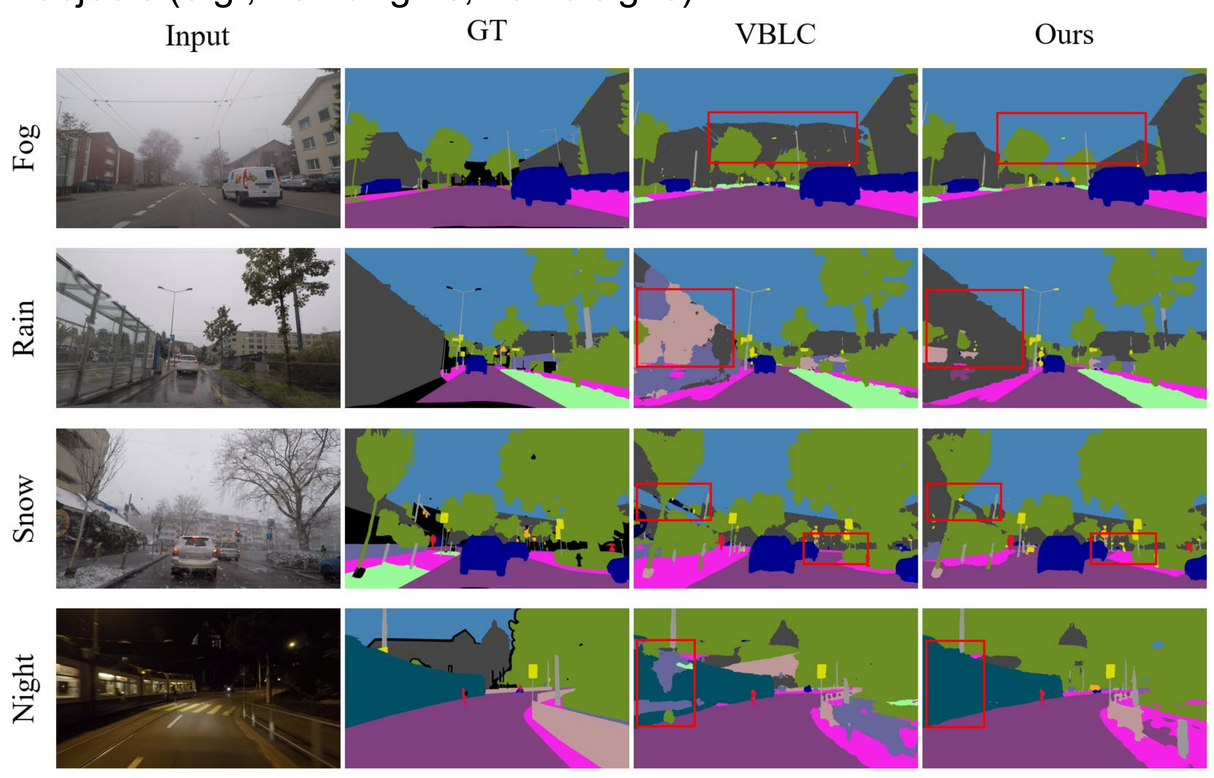
Comparison to SOTA Methods

- Our method achieves 64.82%on the DAFormer and 47.97% on DeepLab-v2 in terms of mIoU.
- We have performance gain of 2.98% and 6.39% over VBLC and MIC, respectively, on the DAFormer.
- We achieve 76.84% on the fog, 68.55% on the rain, 64.78% on the snow, and 40.24% on the night in mIoU.
- While VBLC achieves 72.78% on the fog, 65.53% on the rain, 60.45% on the snow, and 41.74% on the night in mIoU.

	ACDC-FRS	ACDC-night	ACDC
MIC	-	-	58.43 (6.39↑)
VBLC	66.23	41.74	61.84 (2.98↑)
Ours	71.26	40.24	**64.82**

Qualitative Results

- Our method has a large visual improvement, especially in the FRS domain.
- Our work demonstrates a proficiency in capturing details on large objects, especially in the sky, which is outperformed by other methods.
- It is excellent in recognizing context details, particularly in small objects (e.g., traffic lights, traffic signs).



(b) Qualitative results on ACDC dataset

Discussion & Conclusion

- We propose an unsupervised domain adaptation method for semantic segmentation in adverse weather conditions by training two subdomain teachers, one for the fog, rain, and snow (FRS) conditions and another for the night subdomain individually.
- The knowledge of two subdomains is distilled to the student in an online manner with symmetric cross-entropy.
- Our method outperforms VBLC and MIC on the ACDC dataset.
- Although our method outperforms on FRS, it achieves a relatively low mIoU on the night domain.
  - This is because the number of night samples is scarce compared to FRS and large difference in illumination between the sky in the night and the sky in the FRS.
  - We are addressing this as a future work.

[1] M. Li, B. Xie, S. Li, C. H. Liu, and X. Cheng, "Vblc: Visibility boosting and logit-constraint learning for domain adaptive semantic segmentation under adverse conditions," in Proceedings of the AAAI Conference on Artificial Intelligence, 2023
[2] C. Sakaridis, D. Dai, and L. Van Gool, "Acdc: The adverse conditions dataset with correspondences for semantic driving scene understanding," in Proceedings of the IEEE/CVF International Conference on Computer Vision, 2021
[3] L. Hoyer, D. Dai, and L. Van Gool, "Daformer: Improving network architectures and training strategies for domain-adaptive semantic segmentation," in Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, 2022
[4] L. Hoyer, D. Dai, H. Wang, and L. Van Gool, "Mic: Masked image consistency for context-enhanced domain adaptation," in Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, 2023