Similarity Min-Max: Zero-Shot Day-Night Domain Adaptation

Rundong Luo Wenjing Wang Wenhan Yang Jiaying Liu

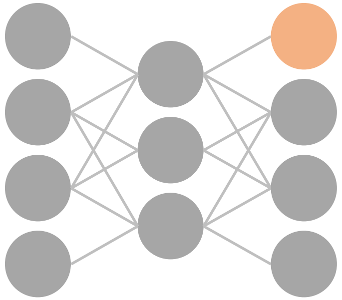
Presenter: Rundong Luo

Wangxuan Institute of Computer Technology, Peking University *Peng Cheng Laboratory*

Background

Low light hinders both human perception and **model performance**

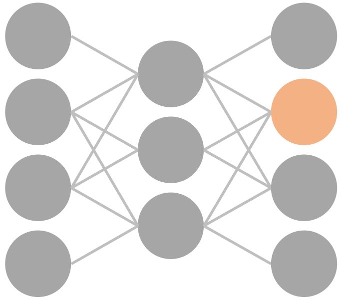
Normal light



Cat (1.00)

Performance drop

Low light



Chair (0.98) ×

Background

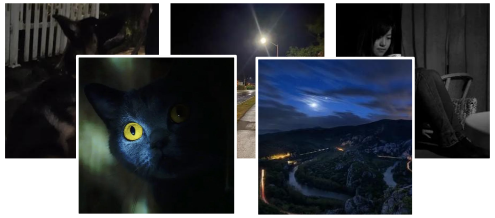
Solutions to improve the model's performance in nighttime scenarios:

Day-Night Domain Adaptation:

- Data: labeled daytime + unlabeled nighttime

Labeled daytime data

+



Unlabeled nighttime data

adapt

Nighttime conditions

Background

Solutions to improve the model's performance in nighttime scenarios:

Day-Night Domain Adaptation:

- Data: labeled daytime + unlabeled nighttime

Our task, Zero-Shot Day-Night Domain Adaptation:

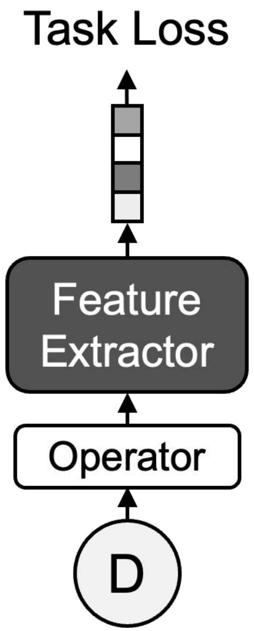
- Data: labeled daytime data **only**

Labeled daytime data

adapt

Nighttime conditions

Motivation

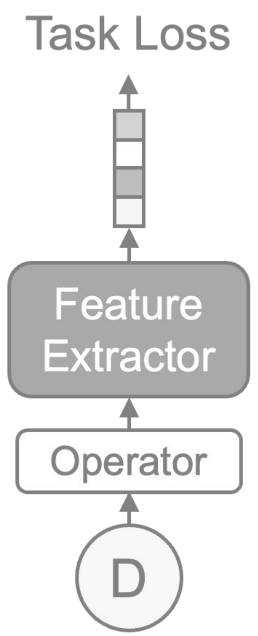


Operator-based [1]

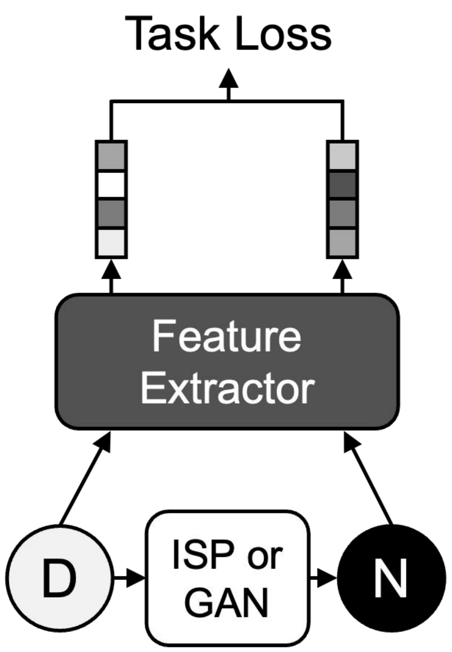
Model-Level: Not robust to complex real-world scenes

[1] Lengyel et al. Zero-Shot Day-Night Domain Adaptation with a Physics Prior. In ICCV, 2021.

Motivation



Operator-based [1]



Darkening-based [2,3]

Image-Level
- ISP: device-dependent
- GAN: requires task-specific nighttime data

[1] Lengyel et al. Zero-Shot Day-Night Domain Adaptation with a Physics Prior. In ICCV, 2021.
[2] Cui et al. Multitask AET with Orthogonal Tangent Regularity for Dark Object Detection. In ICCV, 2021.
[3] Sakaridis et al. Guided Curriculum Model Adaptation for semantic nighttime image segmentation. In ICCV 2019.

Motivation

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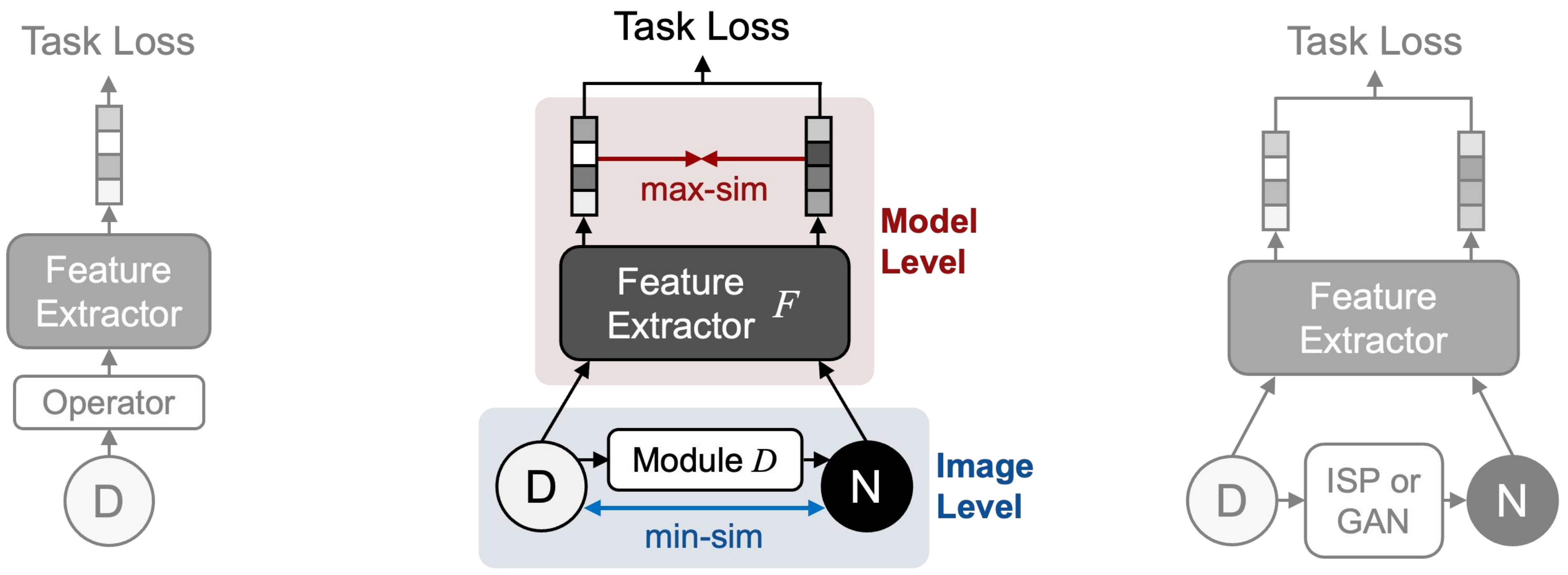

Operator-based [1] | Our method | Darkening-based [2,3]

Joint image-level & model-level optimization

[1] Lengyel et al. Zero-Shot Day-Night Domain Adaptation with a Physics Prior. In ICCV, 2021.
[2] Cui et al. Multitask AET with Orthogonal Tangent Regularity for Dark Object Detection. In ICCV, 2021.
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Problem Formulation

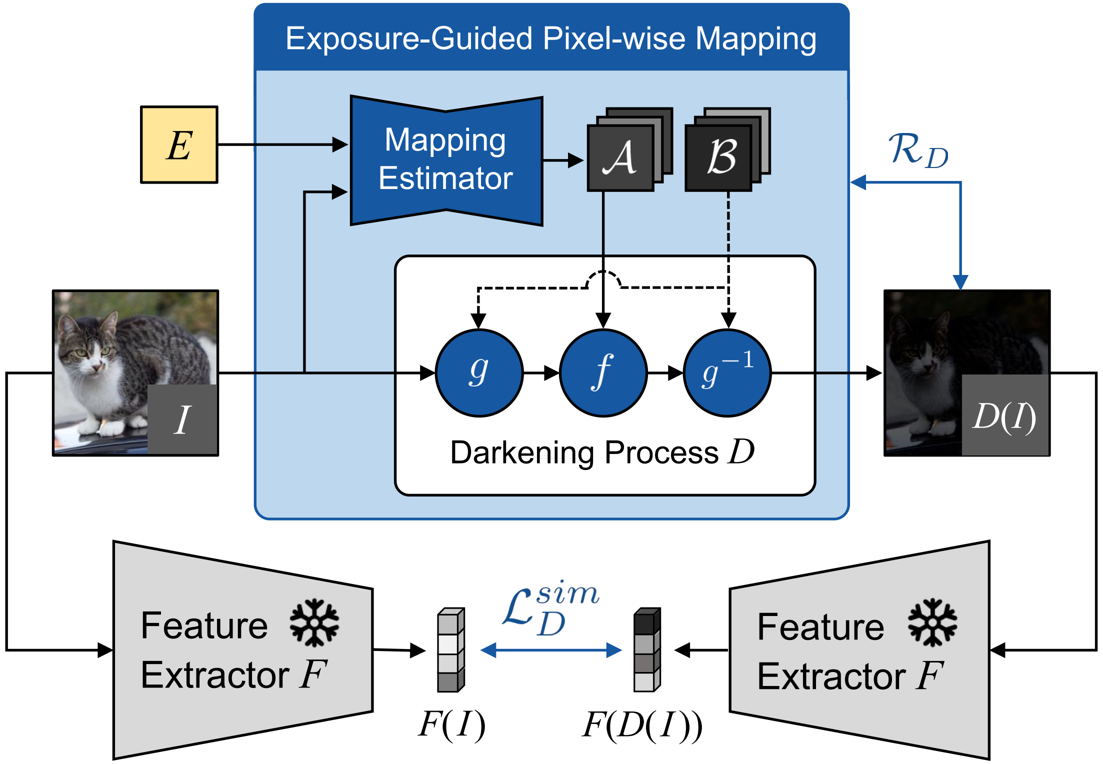
- Given a feature extractor F, we hope it to be robust to illumination changes, *i.e., the* daytime image I and its darkened version $D(I)$ should have similar representations.
- Formulation: $$\max_{\theta_F} \min_{\theta_D} \quad \mathrm{Sim}(F(I), F(D(I))) \quad (1)$$
- Add regularization to avoid trivial solutions:

$$\max_{\theta_F} \min_{\theta_D} \ \mathrm{Sim}(F(I), F(D(I))) + \mathcal{R}_D(\theta_D) - \mathcal{R}_F(\theta_F) \quad (2)$$

- How to design darkening module D and regularizer R_D, R_F?

Training Framework

- Image-Level Darkening
  - **Regularization ($\mathcal{R}_D$)**
    - Total variance loss
    - Color consistency loss
    - Exposure alignment loss
  - **Similarity loss ($\mathcal{L}_D^{sim}$)**
    - Cosine similarity



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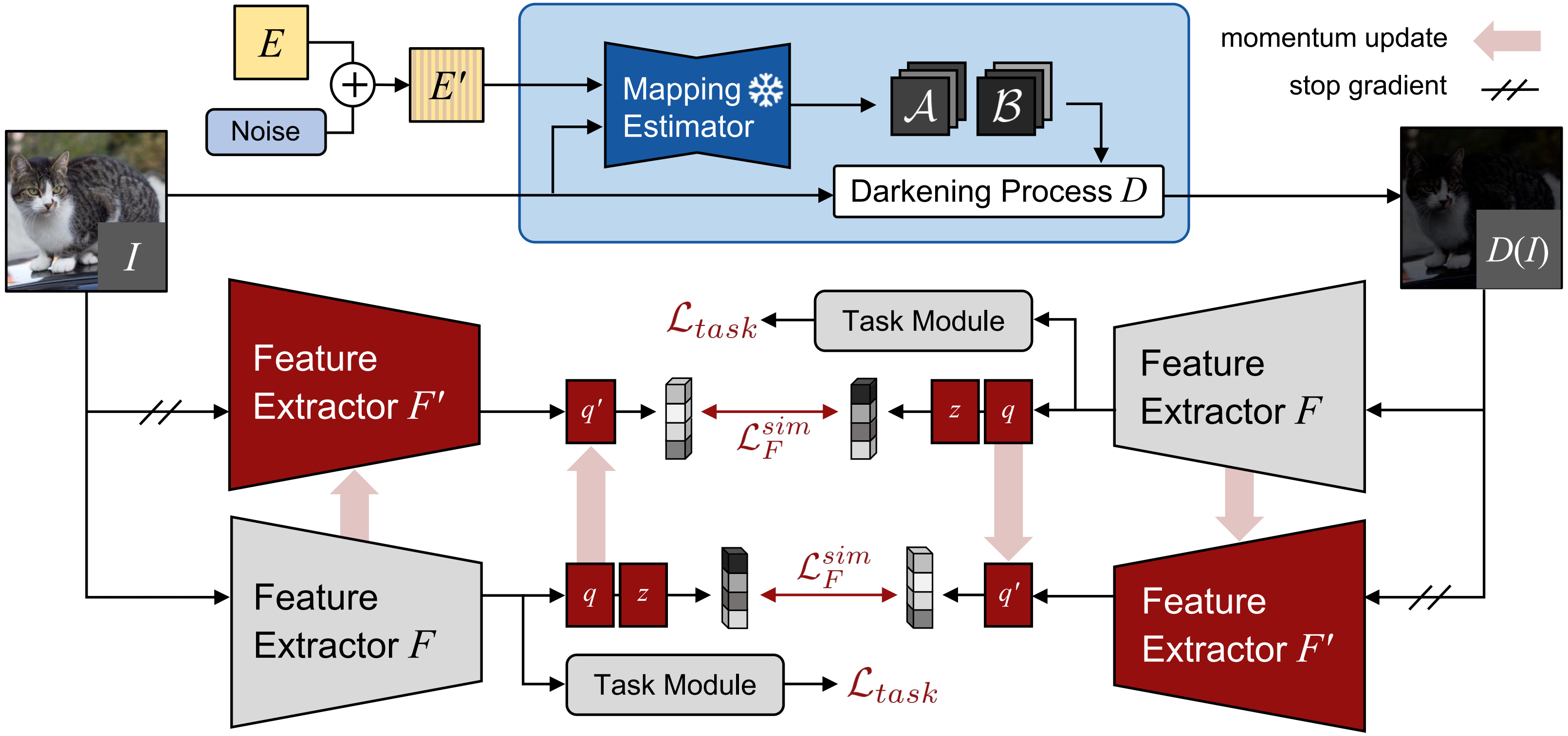
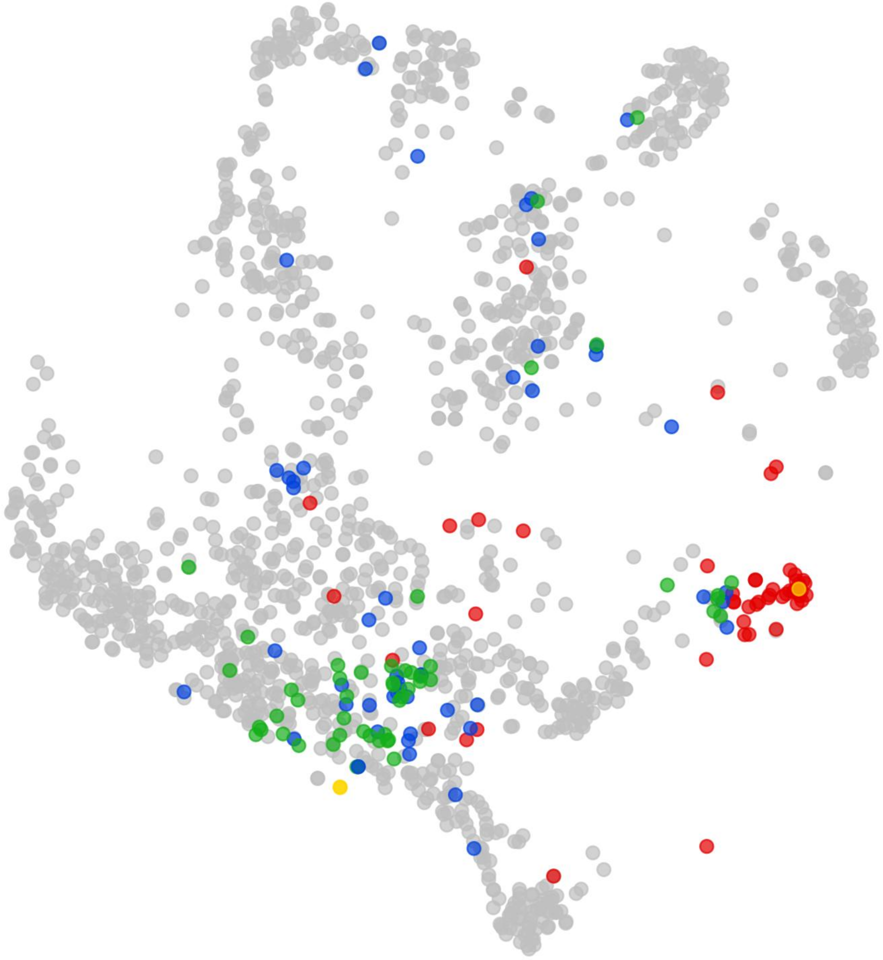
Training Framework

- Image-Level Darkening
- Model-Level Adaptation
  - **Regularization ($\mathcal{R}_F$)**
    - Task loss
  - **Similarity loss ($\mathcal{L}_F^{sim}$)**
    - BYOL loss

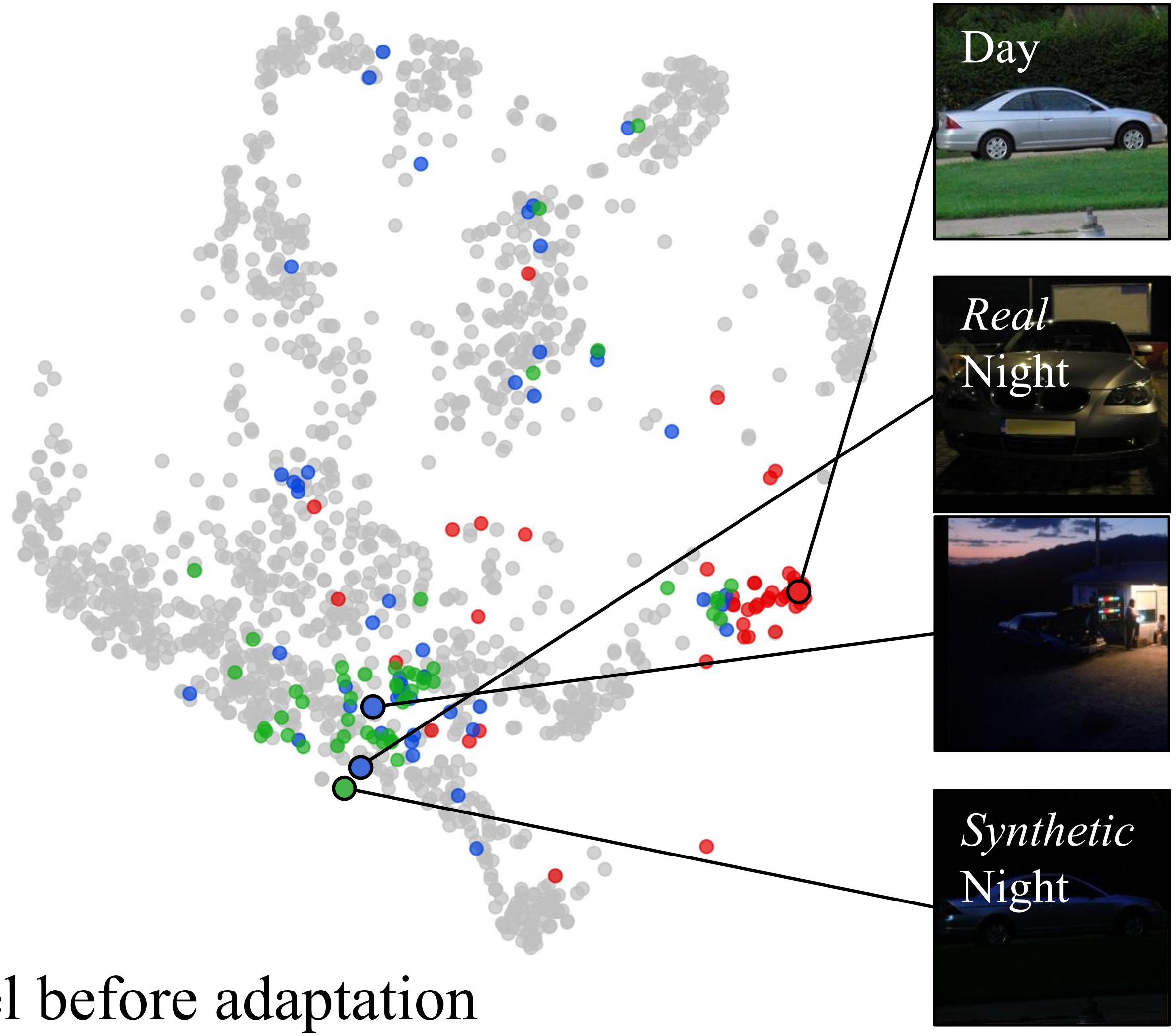


Proof of Concept



Model before adaptation

Proof of Concept



Model before adaptation

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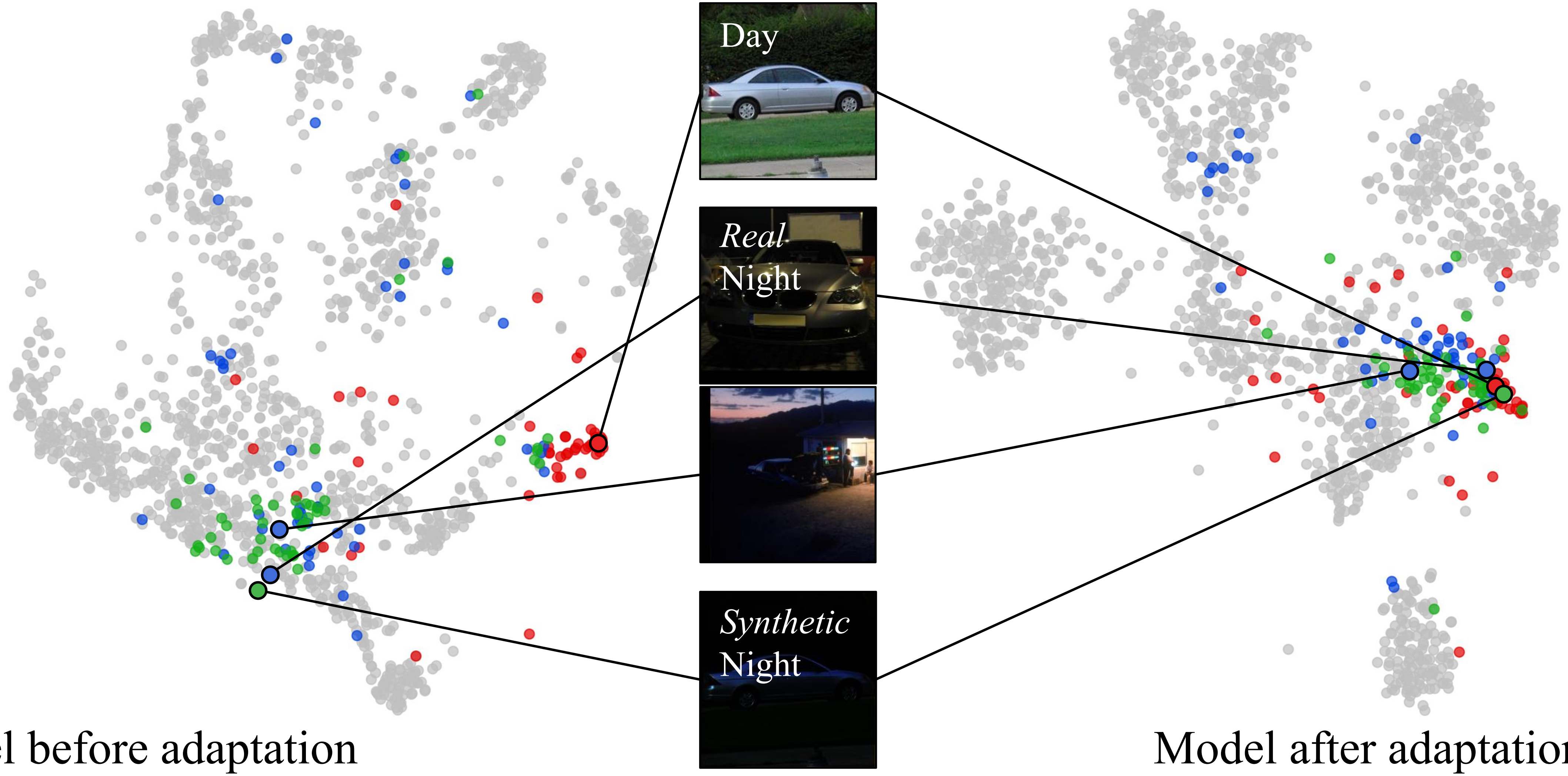
Proof of Concept



Model before adaptation

Model after adaptation

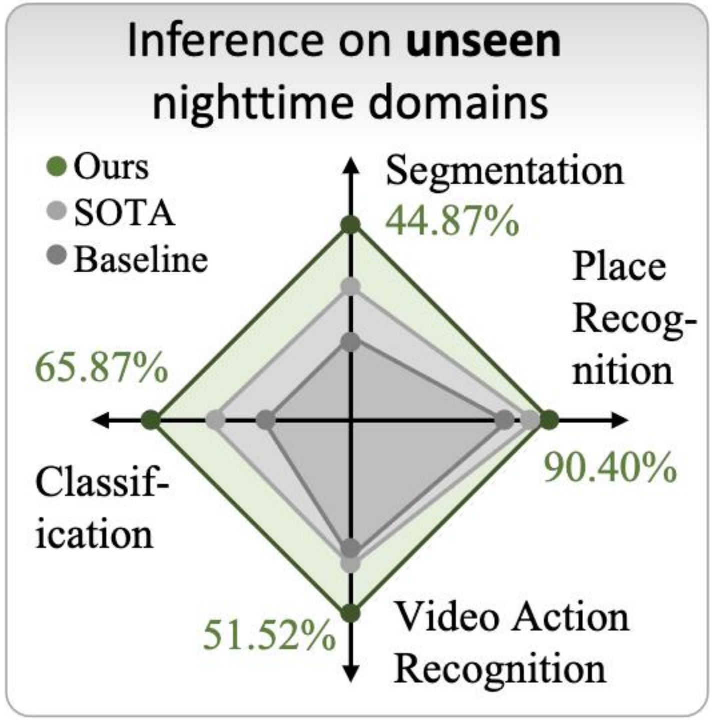
Tasks and datasets for evaluation

- Low-Light image classification: CODaN
- Nighttime semantic segmentation: Nighttime Driving, Dark-Zurich
- Visual place recognition: Tokyo 24/7
- Low-Light video action recognition: ARID

Baselines

- Low-light image (video) enhancement
- Zero-shot domain adaptation
- Domain generalization

Experiments



I. Classification

Method	Top-1 (%)
ResNet-18 [18]	53.32
Low-Light Enhancement	
EnlightenGAN [23]	56.68
LEDNet [63]	57.40
Zero-DCE++ [30]	57.96
RUAS [33]	58.36
SCI [34]	58.68
URetinexNet [56]	58.72
Domain Generalization	
MixStyle [62]	53.12
IRM [1]	54.52
AdaBN [31]	54.25
Zero-Shot Day-Night Domain Adaptation	
MAET† [8]	56.48
CIConv [29]	60.32
Ours	**65.87**

II. Segmentation

Method	Nighttime Driving	Dark-Zurich
RefineNet [32]	34.3	30.6
Low-Light Enhancement		
EnlightenGAN [23]	25.2	24.9
Zero-DCE++ [30]	32.7	28.3
RUAS [33]	25.1	23.4
SCI [34]	28.6	25.7
URetinexNet [56]	28.1	24.0
LEDNet [63]	27.6	26.6
Domain Generalization		
AdaBN [31]	37.2	31.1
RobustNet [6]	33.0	34.5
SAN-SAW [38]	28.1	16.0
Zero-Shot Day-Night Domain Adaptation		
MAET [8]	28.1	26.4
CIConv [29]	41.2	34.5
Ours	**44.9**	**40.2**

III. Visual Place Recognition

Method	mAP (%)
Zero-Shot Day-Night Domain Adaptation	
EdgeMAC [42]	75.9
U-Net jointly [21]	79.8
GeM [43]	85.0
CIConv-GeM [29]	88.3
Ours-GeM	**90.4**
Day-Night Domain Adaptation (night images are available for training)	
U-Net jointly [21]	86.5
EdgeMAC + CLAHE [21]	90.5
EdgeMAC + U-Net jointly [21]	90.0

IV. Video Action Recognition

Method	Top-1 (%)
I3D [3]	47.02
Low-Light Video Enhancement	
StableLLVE [59]	45.08
SMOID [22]	47.27
SGZ [61]	46.42
Domain Generalization & Zero-Shot Day-Night Domain Adaptation	
AdaBN [31]	46.17
Ours	**51.52**

II. Nighttime Segmentation

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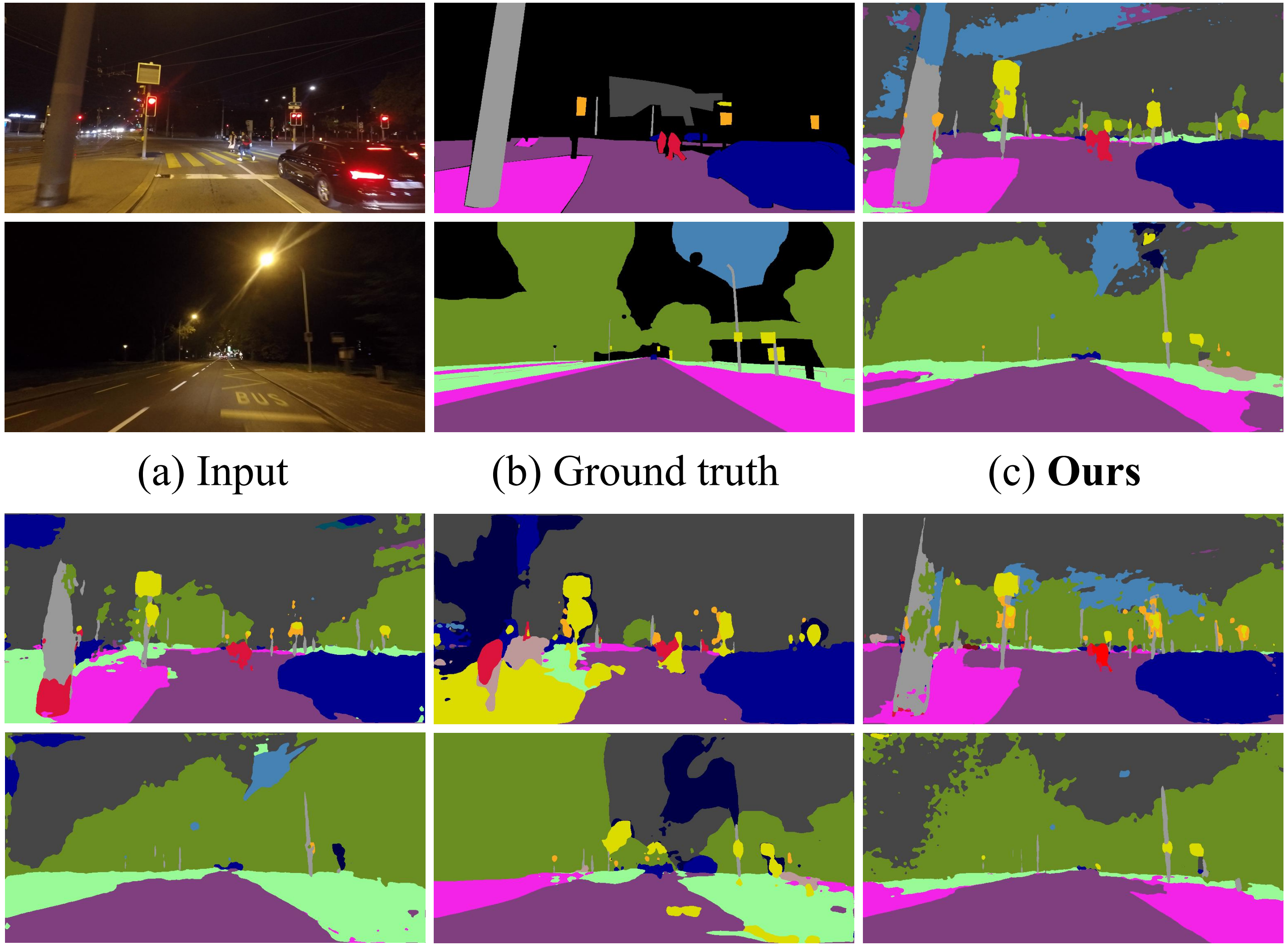

(a) Input (b) Ground truth (c) **Ours**

(d) RefineNet (e) MAET (f) CIConv

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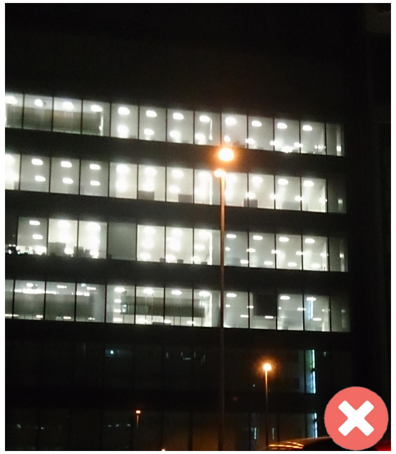
(a) Query



(b) GeM

(c) **Ours**

III. Low-Light Video Action Recognition

Conclusion

- **Task:** zero-shot day-night domain adaptation
- **Framework:** similarity min-max framework
  - A bi-level optimization problem
  - Two-stage training: image-level darkening and model-level adaptation
- **Performance:** state-of-the-art results across multiple downstream tasks.

Thank You

Poster Info:

Room Nord, No. 168

Oct. 5th, 10:30-12:30

Project

Laboratory

Contact: Rundong Luo

rundong_luo@stu.pku.edu.cn / red-fairy.github.io