
# Unsupervised Night Image Enhancement: When Layer Decomposition Meets Light-Effects Suppression

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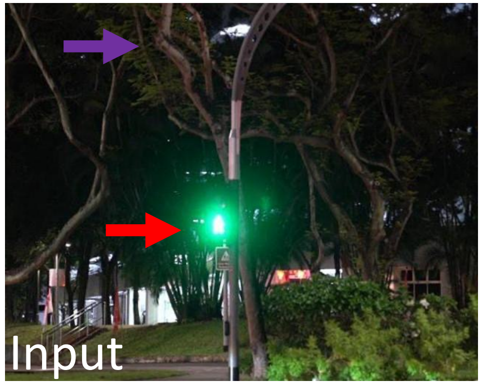
# Night Image Problem

- Low Light:

- Light-Effects/Glare/Floodlight:

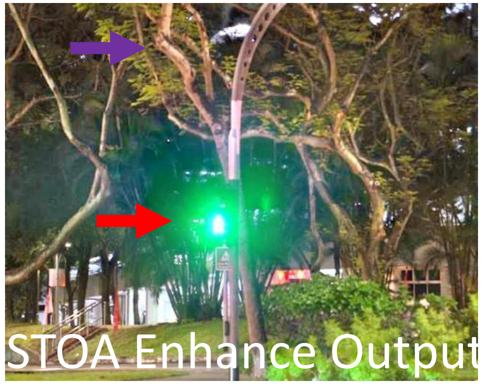
# Motivation

- Existing low-light enhancement methods:




✓ Enhance low-light regions

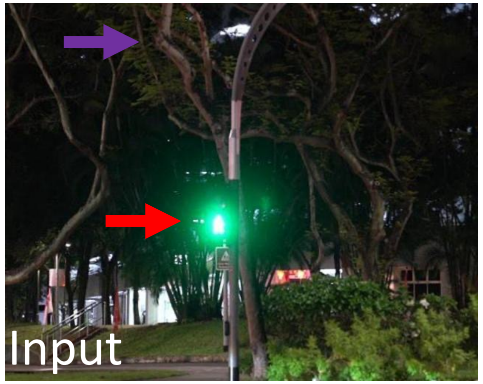
× Over-enhance light-effects regions




Low-light regions

Light-effects regions

- Existing night dehazing methods:



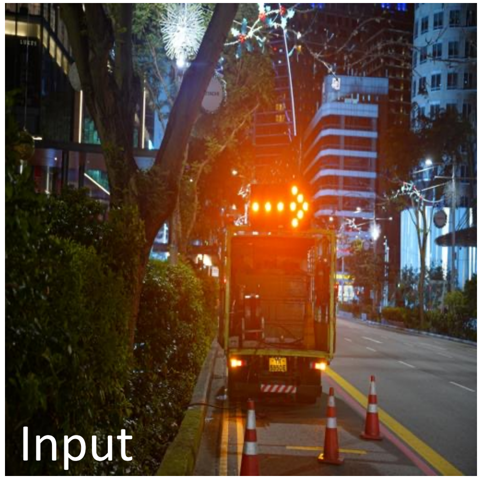

× Enhance low-light regions

✓ Suppress glow; × Suppress light-effects


**Main task:** Boost dark regions, at the same time, suppress light-effects.

# Challenge

➢ Lack of **paired** training data, hard to collect ground truth

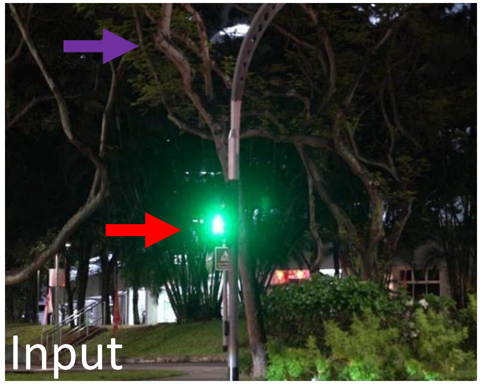

➢ Rendering physically correct night light-effects images is challenging

We propose an **unsupervised** night image enhancement method.

- Model-based Layer Decomposition
- Unpaired Light-Effects Suppression

# Contributions

- To boost dark regions, at the same time, suppress light-effects.

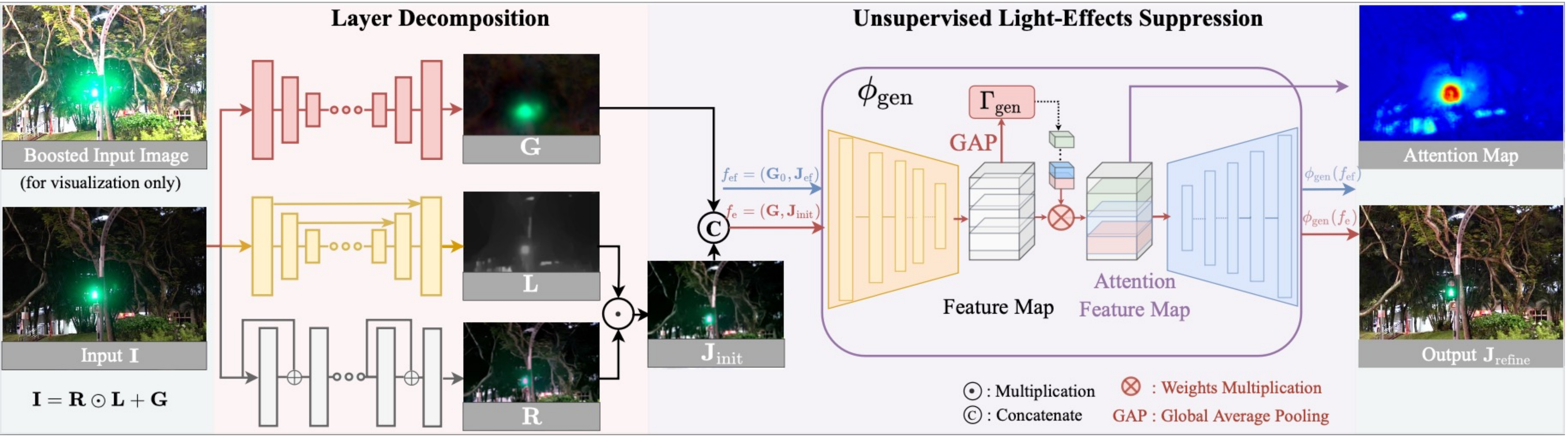



✓ Enhance low-light regions

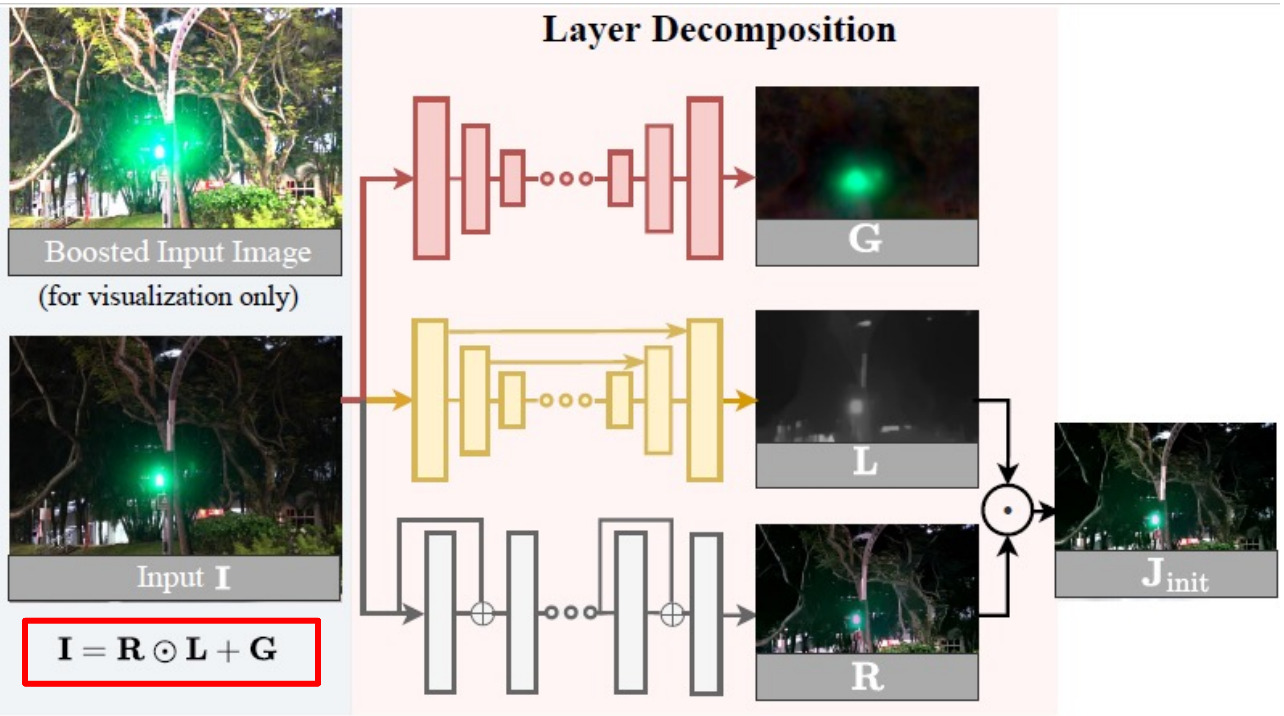
✓ Suppress light-effects regions


- We introduce an **unsupervised learning network**, that integrates layer decomposition and light-effects suppression.
- We propose utilizing the light-effects layer as guidance, to distinguish light-effects from background regions, e.g., **white/multi-colored light-effects**.
- We introduce **unsupervised losses** based on the structure and HF-features consistency, to **restore the background details.**

# Framework: Overview



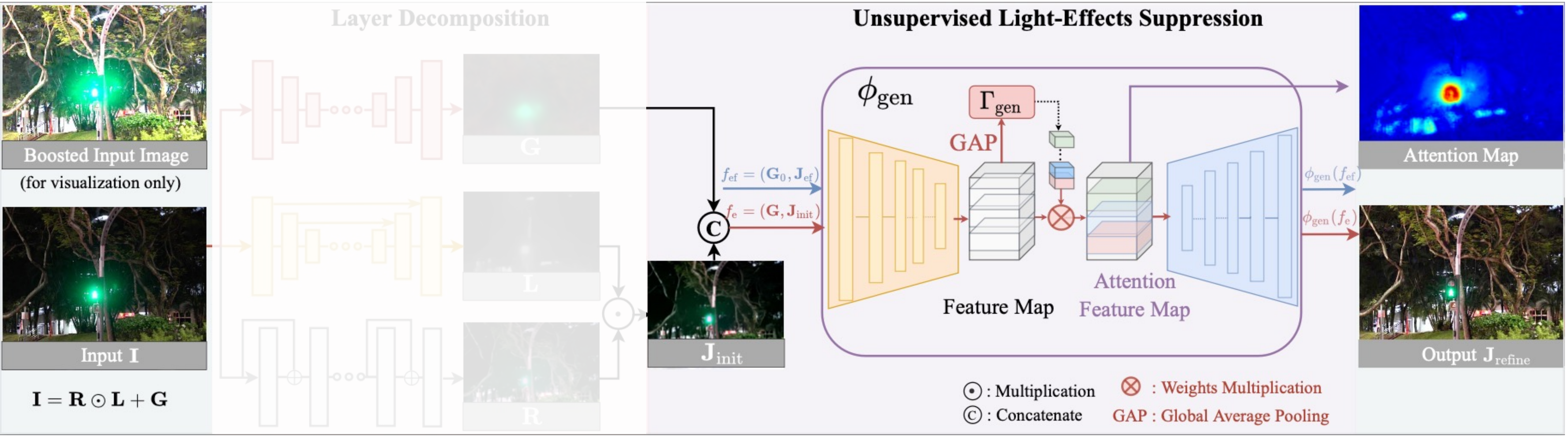
# Framework: Layer Decomposition



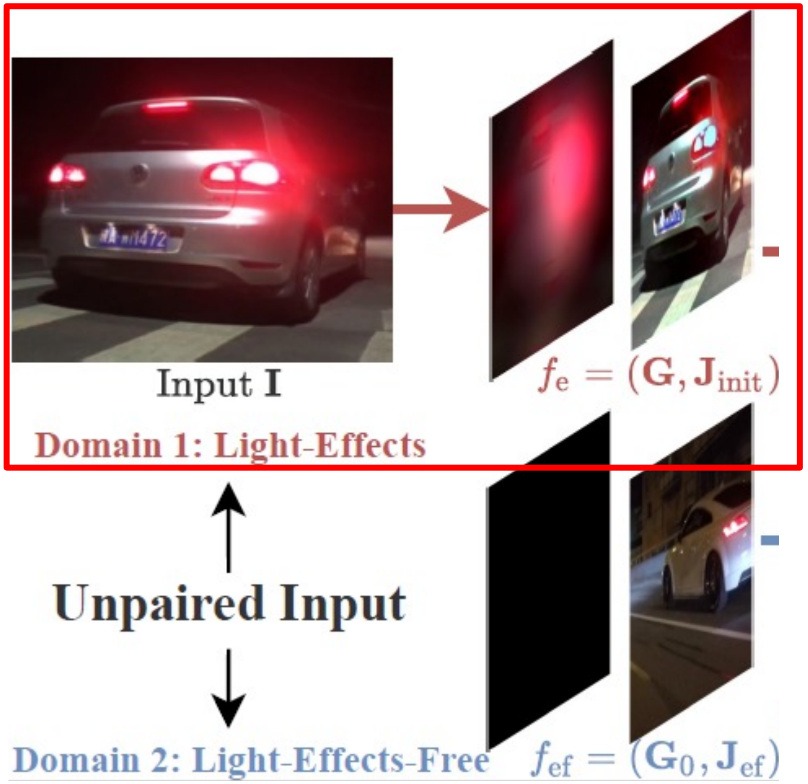

(a) Input (b) Light-Effects Layer **G** (c) Gradient Histogram of **G**

(a) Input **I** (b) **G** (c) **L** (d) **R**

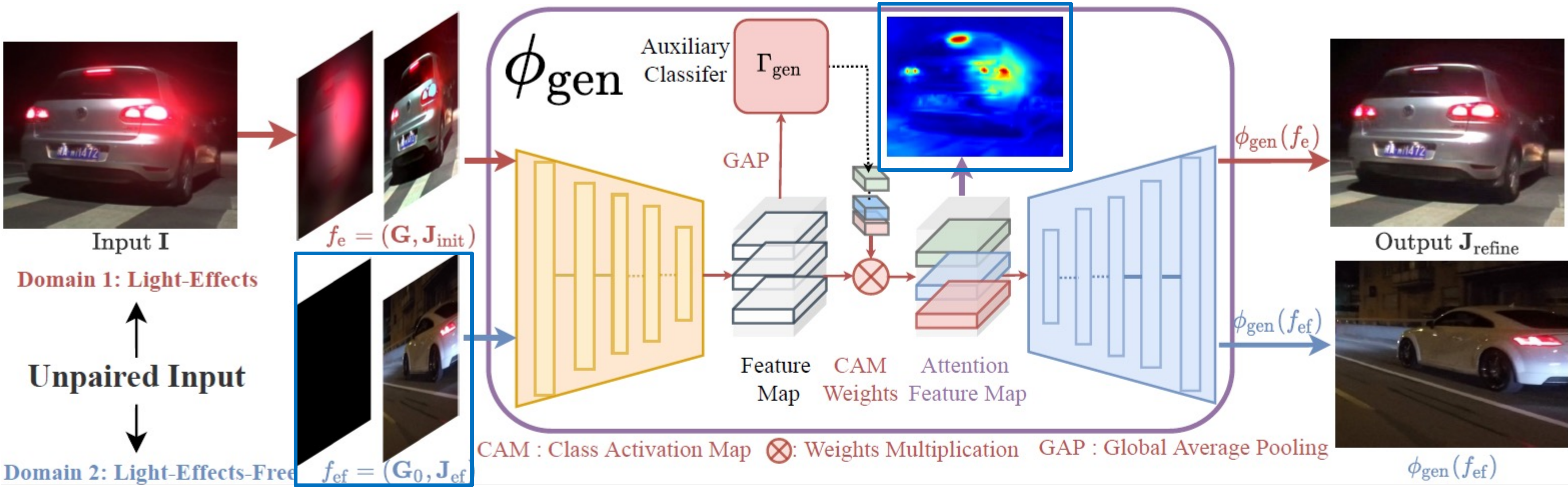
# Framework: Overview



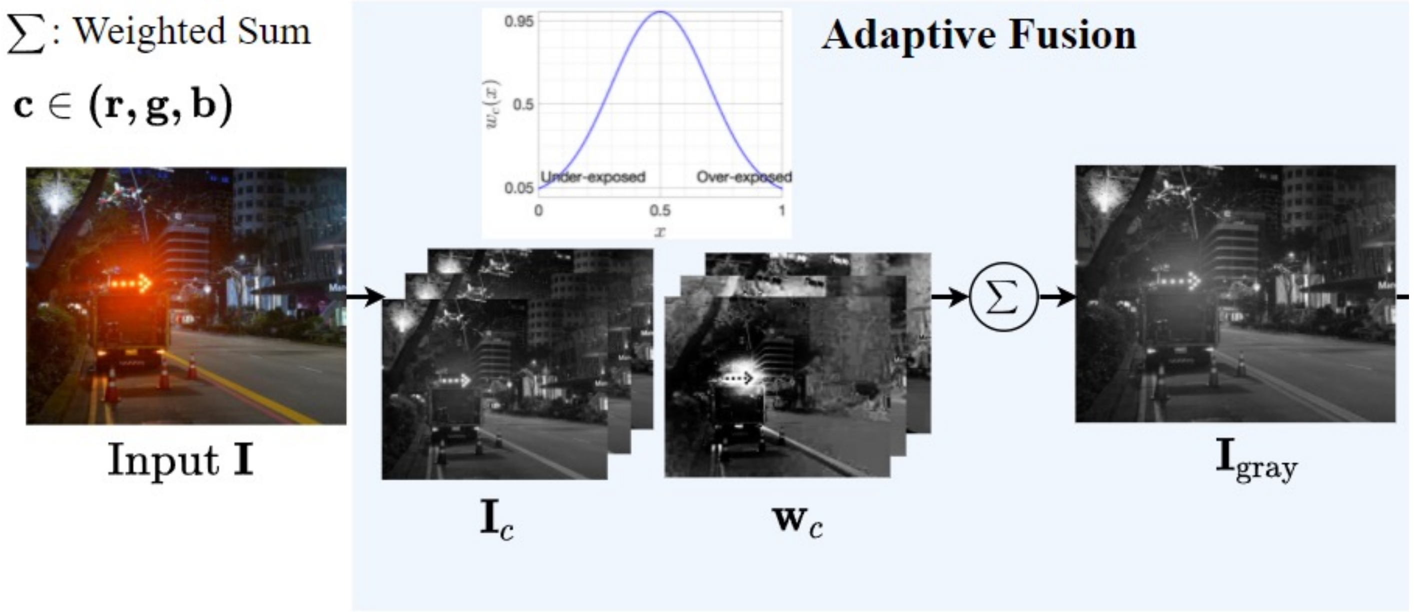
# Framework: Light-effects Suppression



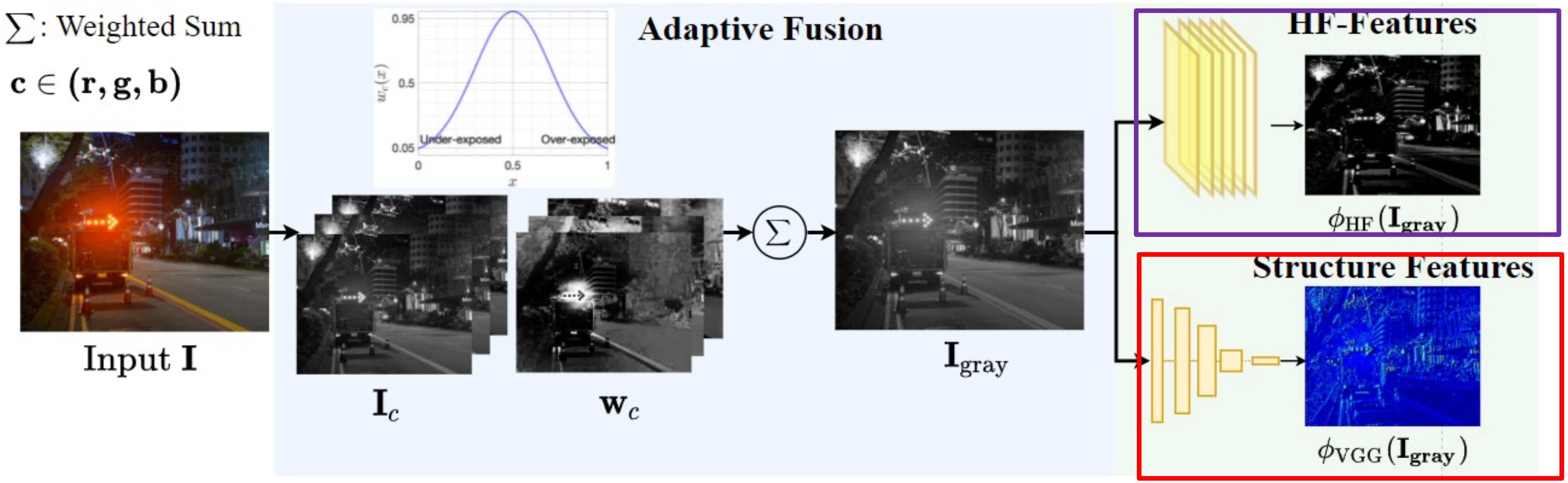
# Framework: Light-effects Suppression

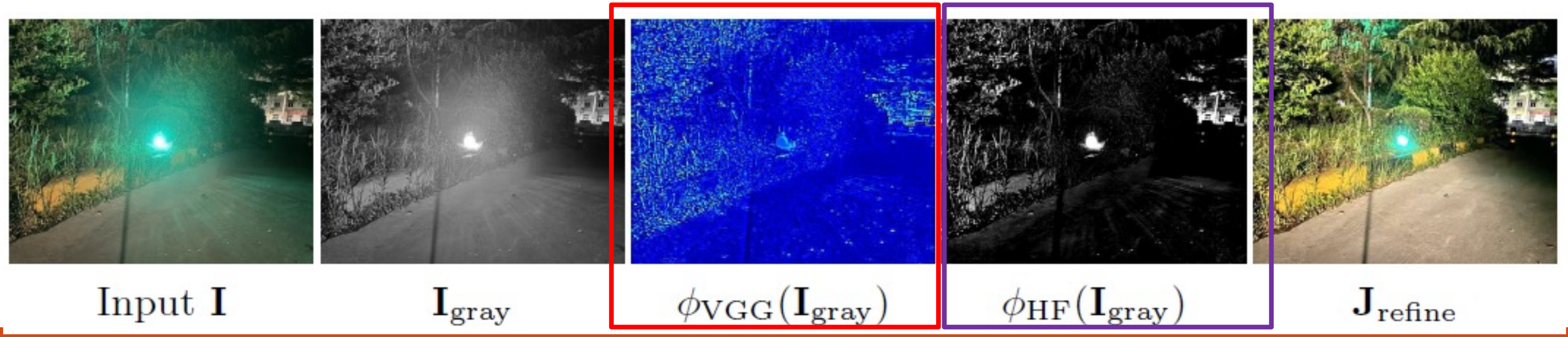


# Structure and HF-features Losses

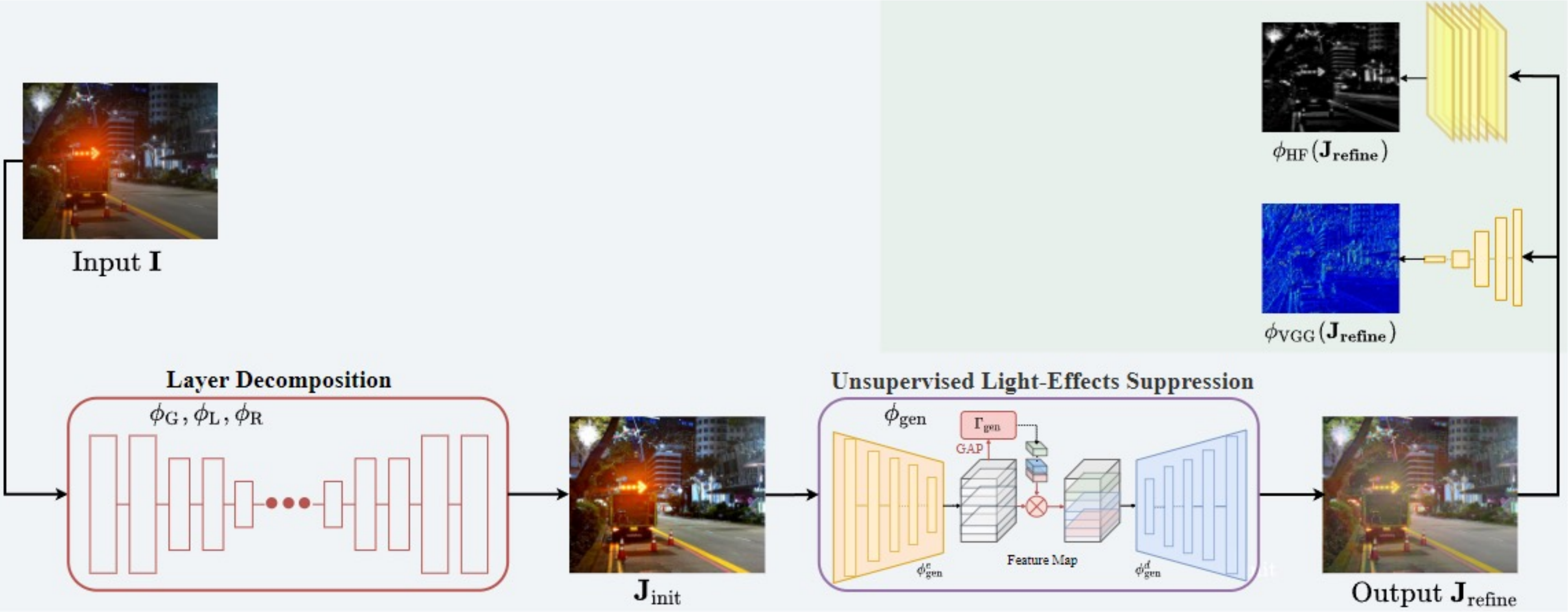


# Structure and HF-features Losses

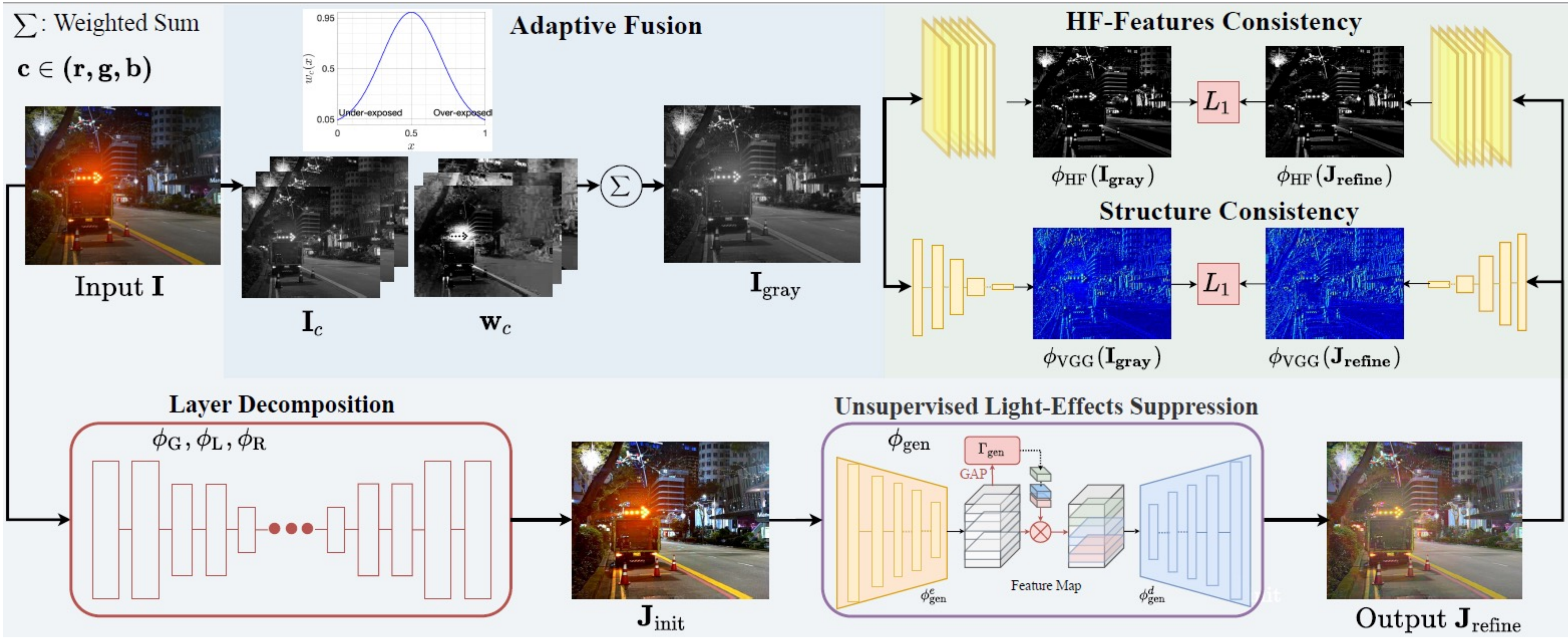


# Structure and HF-features Losses



# Structure and HF-features Losses



# Results on Light-Effects Suppression

## User Study

User study evaluation on the real night data, our method obtained the highest mean (the max score is 7) and lowest standard deviation.

| Three Aspects | EG [15] | Afifi [1] | Yan [38] | Zhang [44] | Li [23] | Sharma [32] | Ours |
|---|---|---|---|---|---|---|---|
| 1.Realism↑ | $3.3 \pm 1.5$ | $5.5 \pm 1.3$ | $3.7 \pm 2.0$ | $3.5 \pm 1.6$ | $3.1 \pm 1.8$ | $2.8 \pm 1.5$ | $\mathbf{6.1 \pm 0.8}$ |
| 2.L.E. Supp.↑ | $1.7 \pm 0.8$ | $3.1 \pm 1.3$ | $4.6 \pm 1.4$ | $3.9 \pm 1.1$ | $5.2 \pm 1.2$ | $3.0 \pm 1.5$ | $\mathbf{6.6 \pm 0.7}$ |
| 3.Visibility↑ | $3.1 \pm 1.6$ | $4.2 \pm 1.5$ | $4.7 \pm 1.5$ | $3.7 \pm 1.1$ | $3.8 \pm 1.5$ | $3.0 \pm 1.4$ | $\mathbf{6.4 \pm 0.7}$ |

**realistic**

**light-effects suppressed**

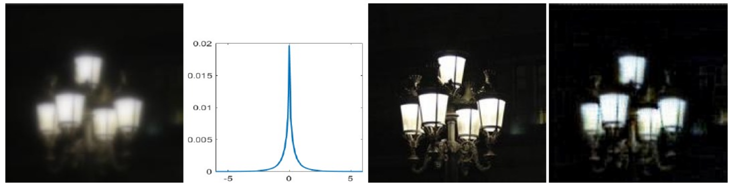
**good visibility**

## Quantitative Evaluation

Quantitative light-effects suppression comparison on the night data.

| Learning | - | UL | ZSL | SL | SL | SSL | Opti | Opti | SSL | UL |
|---|---|---|---|---|---|---|---|---|---|---|
| Datasets | Metrics | EG [15] | ZD+ [19] | RN [7] | Afifi [1] | Yan [38] | Zhang [44] | Li [23] | Sharma [32] | Ours |
| GTA5 [38] | PSNR↑ | 10.94 | 21.13 | 7.79 | 15.47 | 26.99 | 20.92 | 21.02 | 8.14 | **29.79** |
| | SSIM↑ | 0.31 | 0.68 | 0.23 | 0.53 | 0.85 | 0.65 | 0.64 | 0.29 | **0.88** |
| Syn-light-effects [27] | PSNR↑ | 7.38 | 7.84 | 6.39 | 11.31 | 14.88 | 16.30 | 14.66 | 14.00 | **16.95** |
| | SSIM↑ | 0.17 | 0.20 | 0.16 | 0.35 | 0.23 | 0.38 | 0.37 | 0.37 | **0.39** |

Input Ground Truth **Ours**



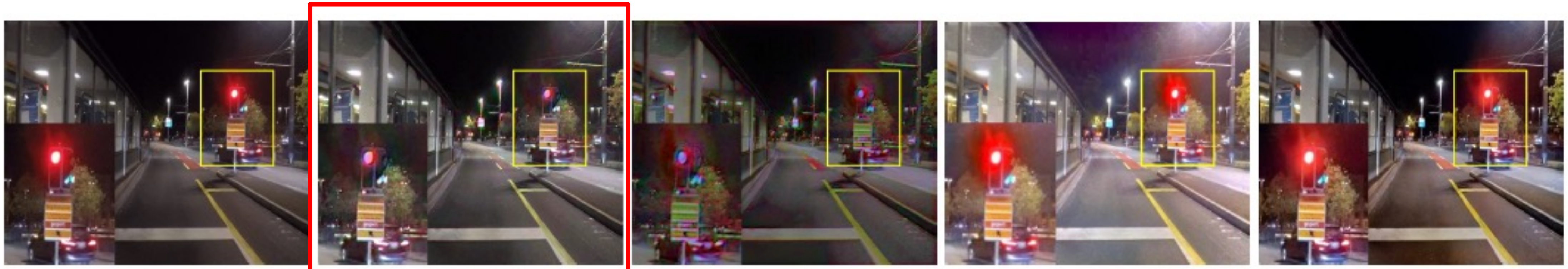
Input APSF Model Ground Truth **Ours**

# Results on Light-Effects Suppression

Input | Ours | Sharma [32] | EG [15] | Afifi [1]

# Results on Light-Effects Suppression

- Dark Zurich Dataset



Input | Ours | Sharma [32] | EG [15] | Afifi [1]

# Results on Low-light Enhancement

Quantitative comparisons on the LOL-test dataset

| Learning | Method | LOL-test | | | |
|---|---|---|---|---|---|
| | | MSE($\times 10^3$)↓ | PSNR↑ | SSIM↑ | LPIPS↓ |
| Opti | LIME [14] | - | 16.760 | 0.560 | 0.350 |
| SL | RetinexNet [7] | 1.651 | 16.774 | 0.462 | 0.474 |
| | KinD++ [47] | 1.298 | 17.752 | 0.760 | **0.198** |
| | Afifi [1] | 4.520 | 15.300 | 0.560 | 0.392 |
| | RUAS [24] | 3.920 | 18.230 | 0.720 | 0.350 |
| ZSL | ZeroDCE [13] | 3.282 | 14.861 | 0.589 | 0.335 |
| SSL | DRBN [40] | 2.359 | 15.125 | 0.472 | 0.316 |
| UL | EnlightenGAN [15] | 1.998 | 17.483 | 0.677 | 0.322 |
| SSL | Sharma [32] | 3.350 | 16.880 | 0.670 | 0.315 |
| UL | Ours | **1.070** | **21.521** | **0.763** | 0.235 |

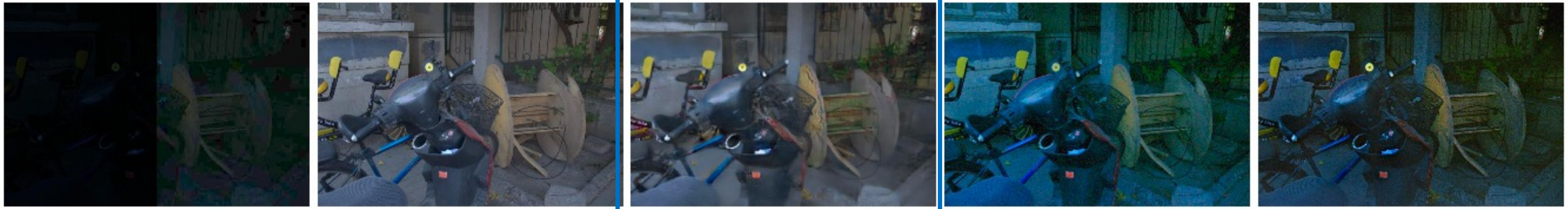
Quantitative comparisons on the *LOL-Real* dataset.

| Learning | NA | Opti | Opti | Opti | ZSL | ZSL | ZSL | ZSL | SL |
|---|---|---|---|---|---|---|---|---|---|
| Method | Input | JED [29] | RRM [21] | SRIE [9] | RDIP [48] | MIRNet [43] | RRDNet [50] | ZD [13] | RUAS [24] |
| PSNR↑ | 9.72 | 17.33 | 17.34 | 17.34 | 11.43 | 12.67 | 14.85 | 20.54 | 15.33 |
| SSIM↑ | 0.18 | 0.66 | 0.68 | 0.68 | 0.36 | 0.41 | 0.56 | 0.78 | 0.52 |
| Learning | SL | SL | SL | SL | SL | SSL | UL | SSL | UL |
| Method | LLNet [25] | RN [7] | DUPE [34] | SICE [6] | Afifi [1] | DRBN [41] | EG [15] | Sharma [32] | Ours |
| PSNR↑ | 17.56 | 15.47 | 13.27 | 19.40 | 16.38 | 19.66 | 18.23 | 18.34 | **25.53** |
| SSIM↑ | 0.54 | 0.56 | 0.45 | 0.69 | 0.53 | 0.76 | 0.61 | 0.64 | **0.88** |

# Results on Low-light Enhancement

- LOL-test dataset

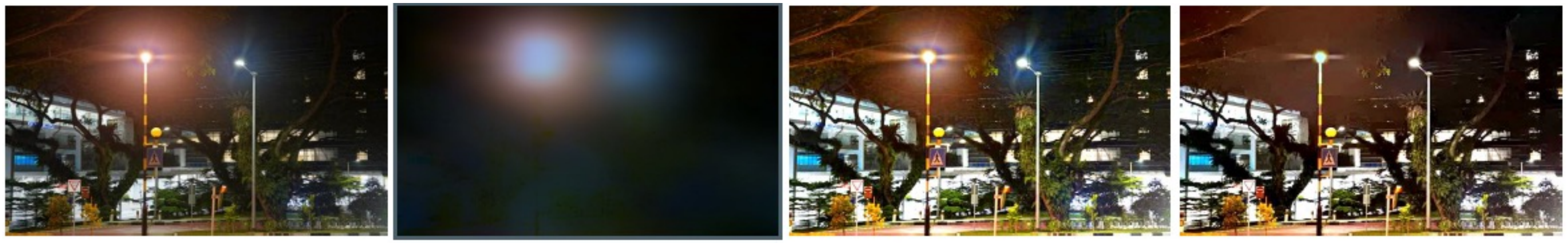
- *LOL-Real* dataset



Input    Ground Truth    Ours    Sharma    EG

# Conclusion

- We presented an **unsupervised learning** framework for night image enhancement, which boost dark regions and suppress light-effects simultaneously.
- With light-effects layer guidance, our method separate **white/multi-colored light-effects** more properly.



Input | Light-Effects Layer | w/o $\mathbf{G}$ guidance | w/ $\mathbf{G}$ guidance

- With unsupervised structure and HF-features consistency loss, our method **restore the background details.**

Input | w/o $\mathcal{L}_{\text{gray-feat}}$ | w/ $\mathcal{L}_{\text{gray-feat}}$

# Thank you!

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**CODES AND MODEL:**

HTTPS://GITHUB.COM/JINYEYING/NIGHT-ENHANCEMENT