Explorable Tone Mapping Operators

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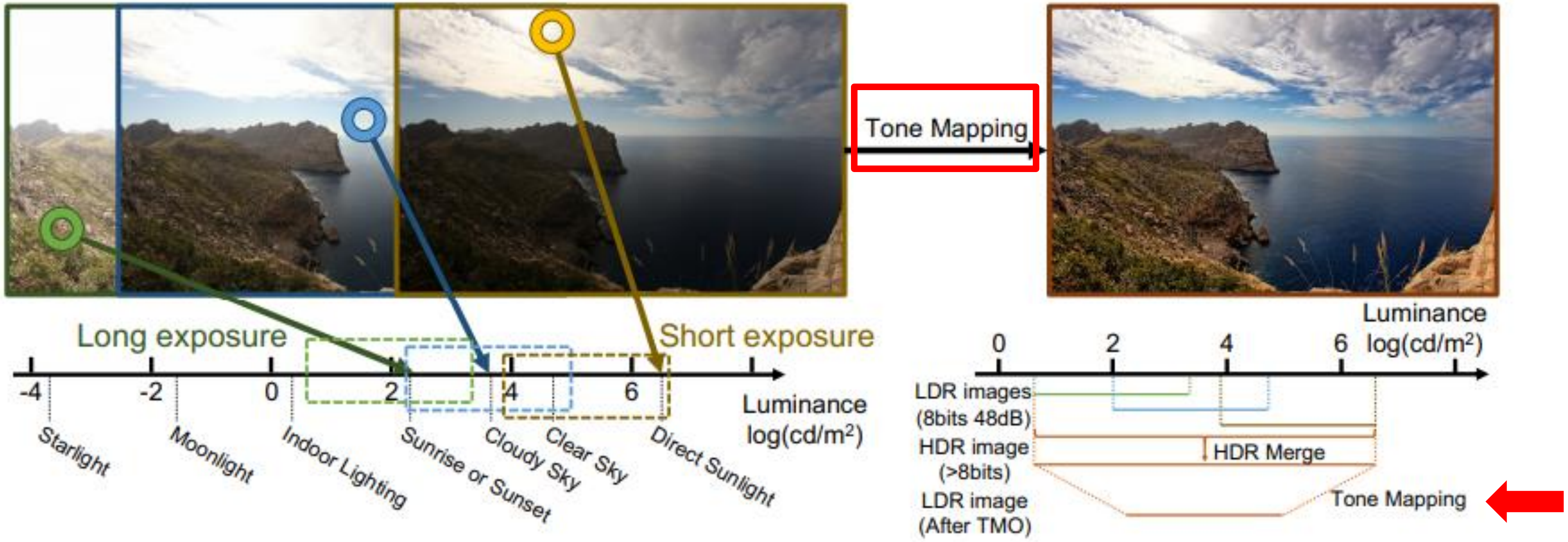
Introduction

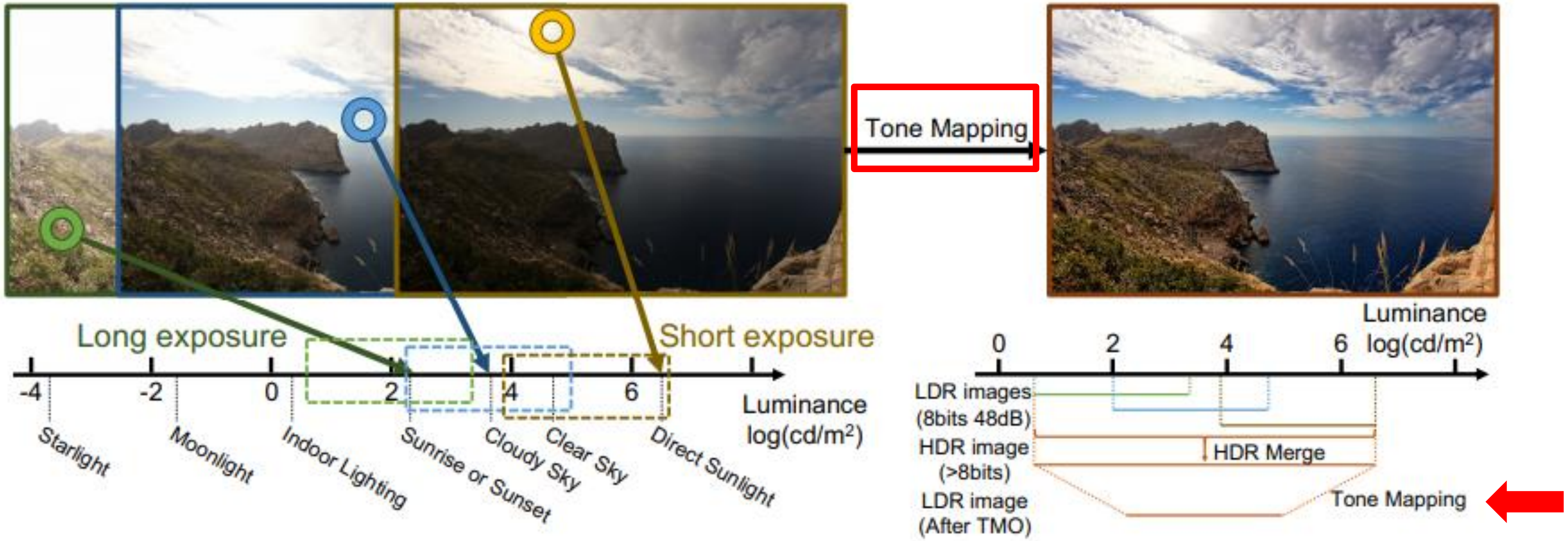
What is Tone Mapping Operator (TMO)?



Tone Mapping Operator plays an essential role in high dynamic range (HDR) imaging.

Source: Y. Ou, P. Ambalathankandy, M. Ikebe, S. Takamaeda, M. Motomura, T. Asai. "Real-time Tone Mapping: A State of the Art Report" May 2020

What is Tone Mapping Operator (TMO)?



It aims to compress HDR images into low dynamic range (LDR) images so that they can be displayed on monitors.

Source: Y. Ou, P. Ambalathankandy, M. Ikebe, S. Takamaeda, M. Motomura, T. Asai. "Real-time Tone Mapping: A State of the Art Report" May 2020

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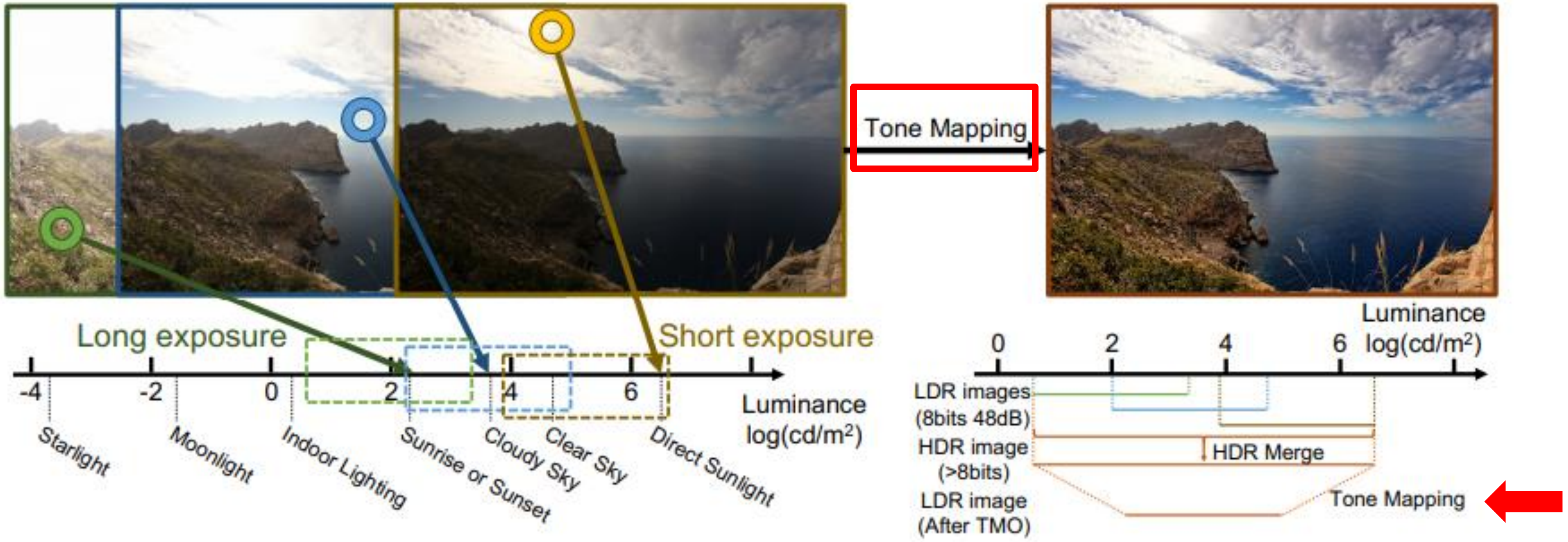
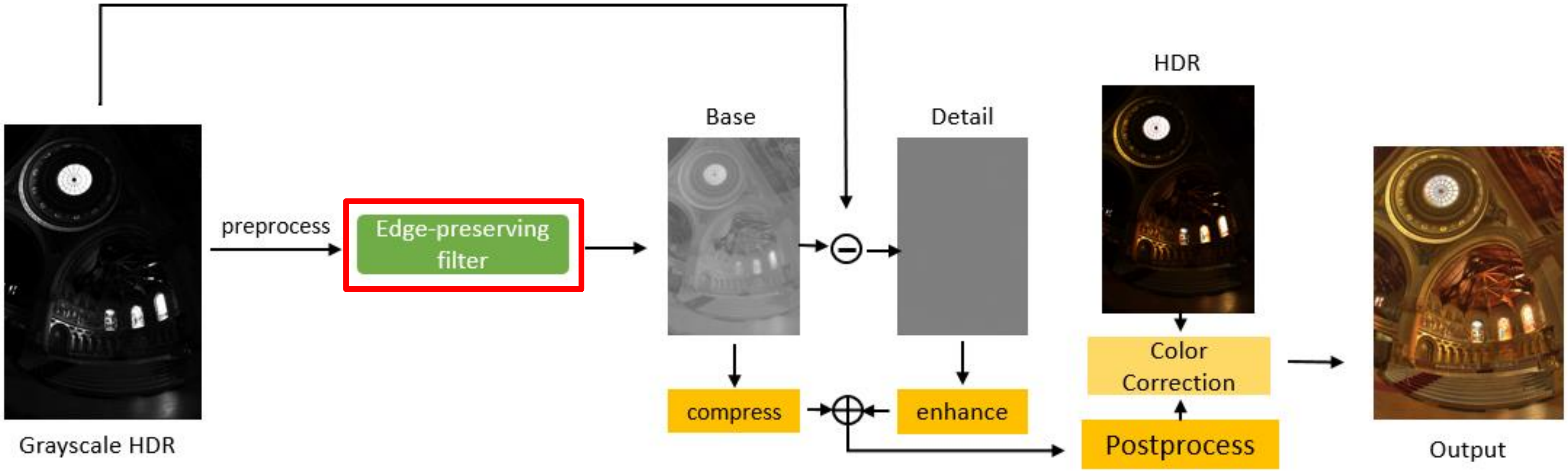


However, compressing HDR images while trying to preserve the perceptual content as much as possible is a challenging task.

Source: Y. Ou, P. Ambalathankandy, M. Ikebe, S. Takamaeda, M. Motomura, T. Asai. "Real-time Tone Mapping: A State of the Art Report" May 2020

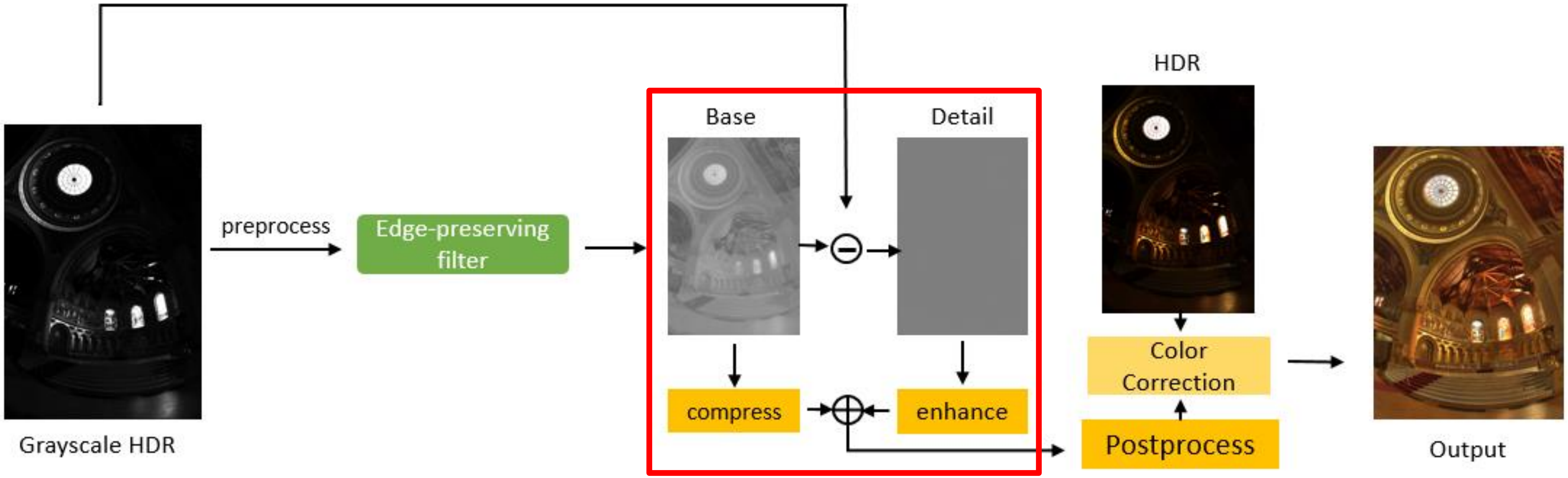
Previous Filtering Method



Filtering methods decompose an HDR image into a smooth base image and a detail image by utilizing an edge-preserving filter.

[1] Frédo Durand, Julie O Brien Dorsey. "Fast bilateral filtering for the display of high dynamic range images", July 2002

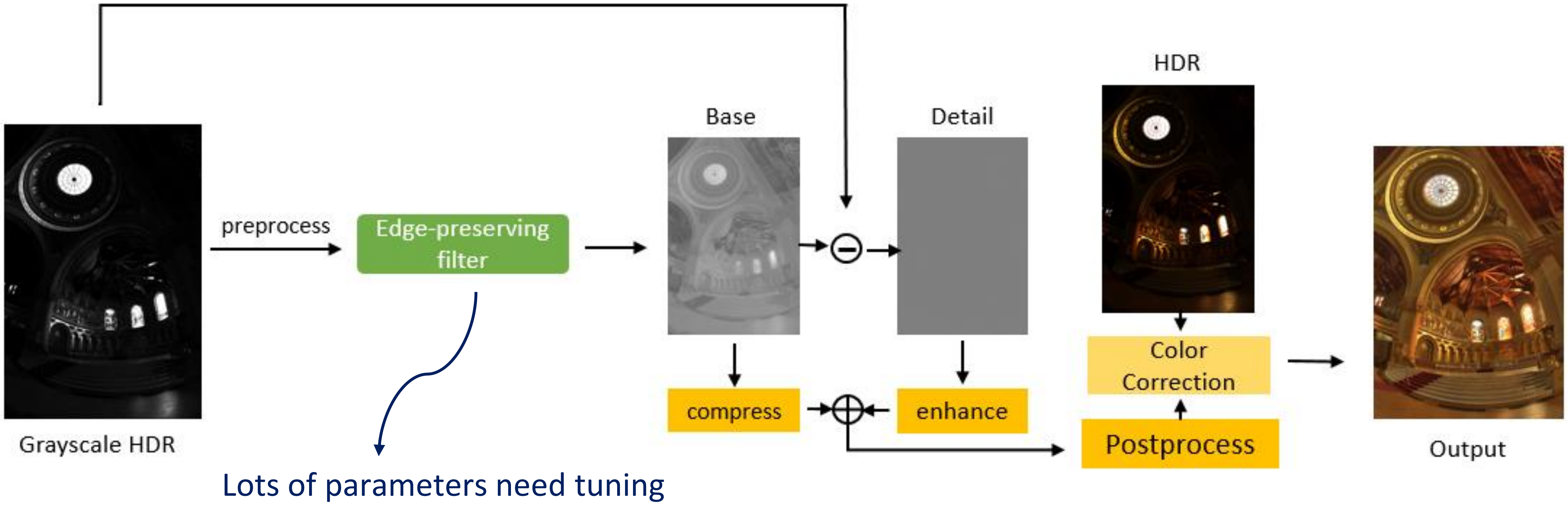
Previous Filtering Method



The base image is usually compressed to reduce the dynamic range, while the detail image is enhanced so that better visual content is preserved.

[1] Frédo Durand, Julie O Brien Dorsey. "Fast bilateral filtering for the display of high dynamic range images", July 2002

Previous Filtering Method

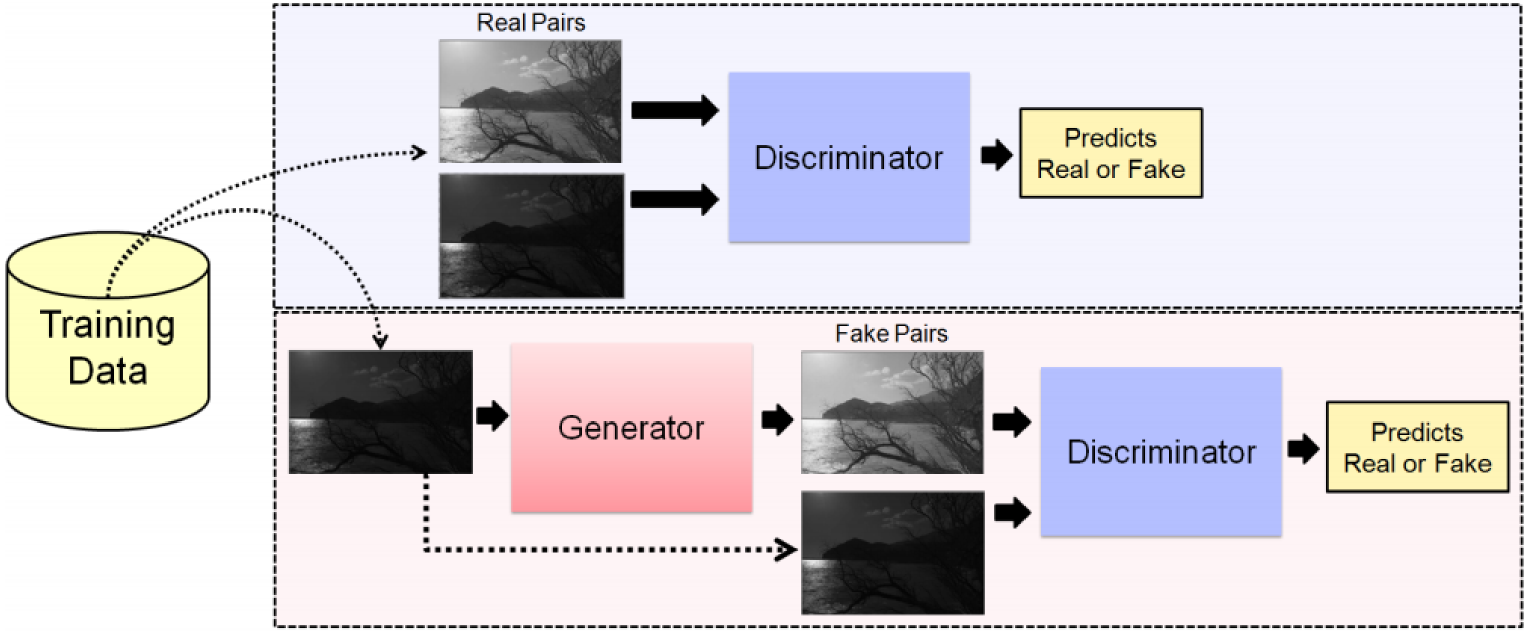


Nevertheless, due to the large amount of parameters, tuning these filters is usually difficult and time-consuming.

[1] Frédo Durand, Julie O Brien Dorsey. "Fast bilateral filtering for the display of high dynamic range images", July 2002

Previous Learning-based Method

Deep TMO[2]



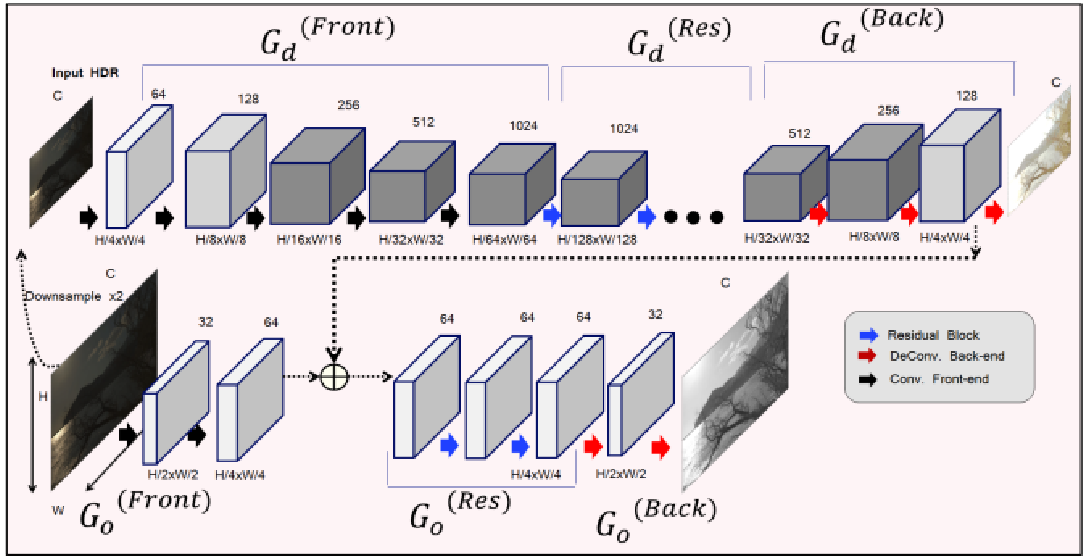
Deep TMO is a deep learning-based method that is able to tone map high-resolution images.

[2] A. Rana, P. Singh, G. Valenzise, F. Dufaux, N. Komodakis, A. Smolic, "Deep Tone Mapping Operator for High Dynamic Range Images" Aug 2019

Previous Learning-based Method

Deep TMO[2]

Multi-scale generator



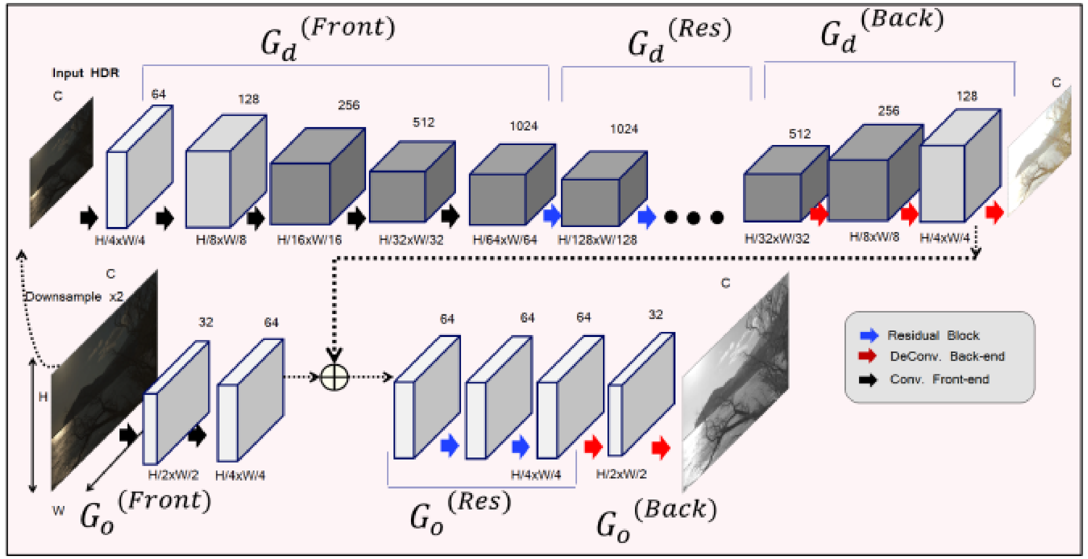
They use cGAN architecture and apply a multi-scale technique to both of the generator and the discriminator to ease artifacts.

[2] A. Rana, P. Singh, G. Valenzise, F. Dufaux, N. Komodakis, A. Smolic, "Deep Tone Mapping Operator for High Dynamic Range Images" Aug 2019

Previous Learning-based Method

Deep TMO[2]

Multi-scale generator

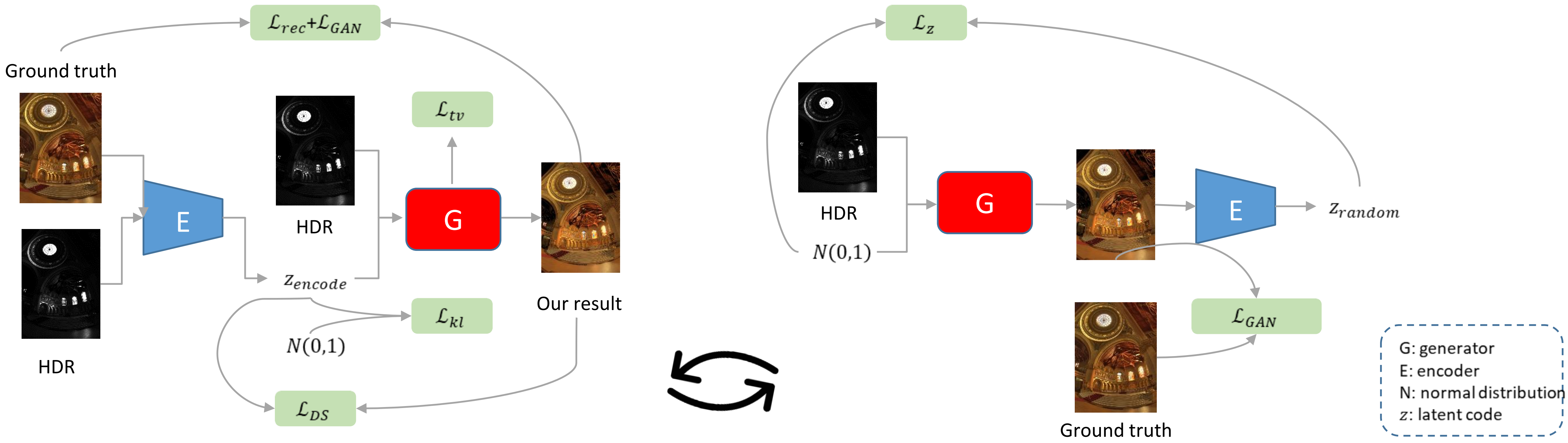


But their method lacks the variety of subjective styles because of the one-to-one mapping characteristic.

[2] A. Rana, P. Singh, G. Valenzise, F. Dufaux, N. Komodakis, A. Smolic, "Deep Tone Mapping Operator for High Dynamic Range Images" Aug 2019

Our Method

An overview of our tone-mapping method



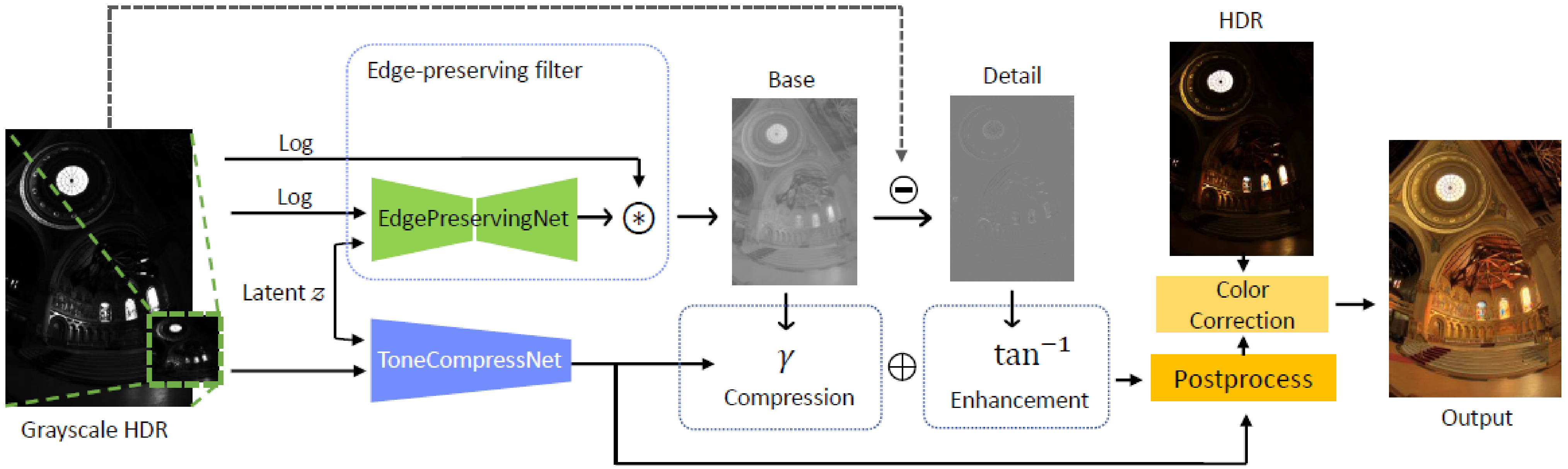
Make generated results follow the target distribution

Make encoded results close to input latent codes

Inspired by the filtering methods, our method is formulated as a BicycleGAN [3] framework.

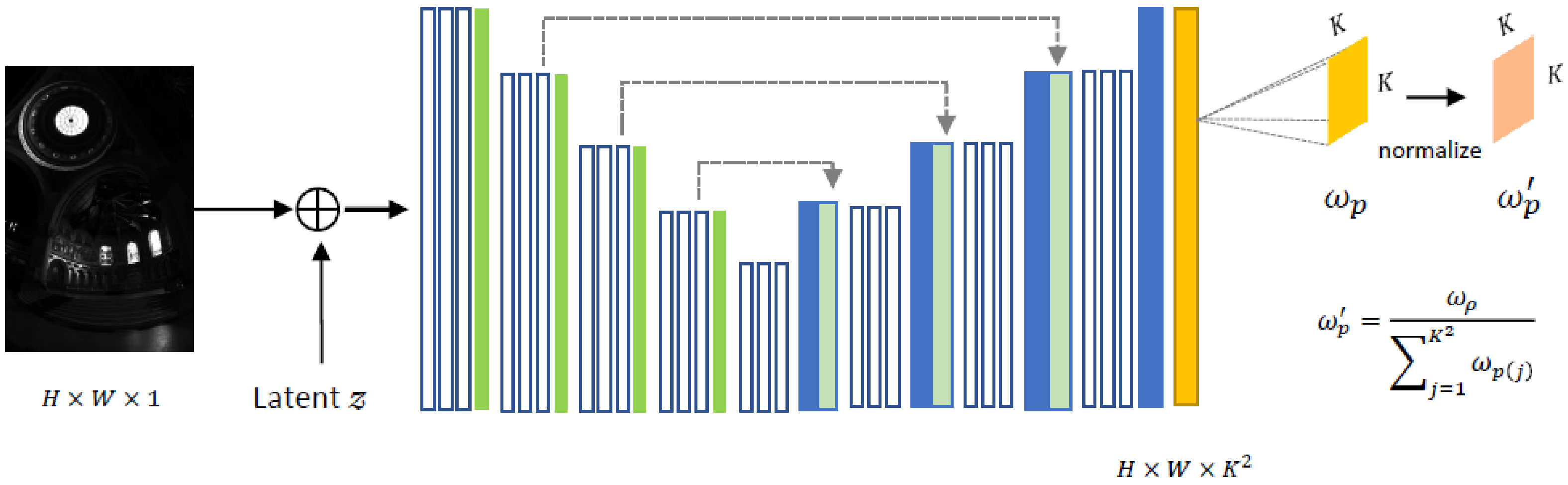
[3] J.Y. Zhu, R. Zhang, D. Pathak, T. Darrell, A. A. Efros, O. Wang, E. Shechtman, "Toward Multimodal Image-to-Image Translation" Nov 2017

The generator pipeline



The generator pipeline comprises two sub-networks: an EdgePreservingNet and a ToneCompressNet.

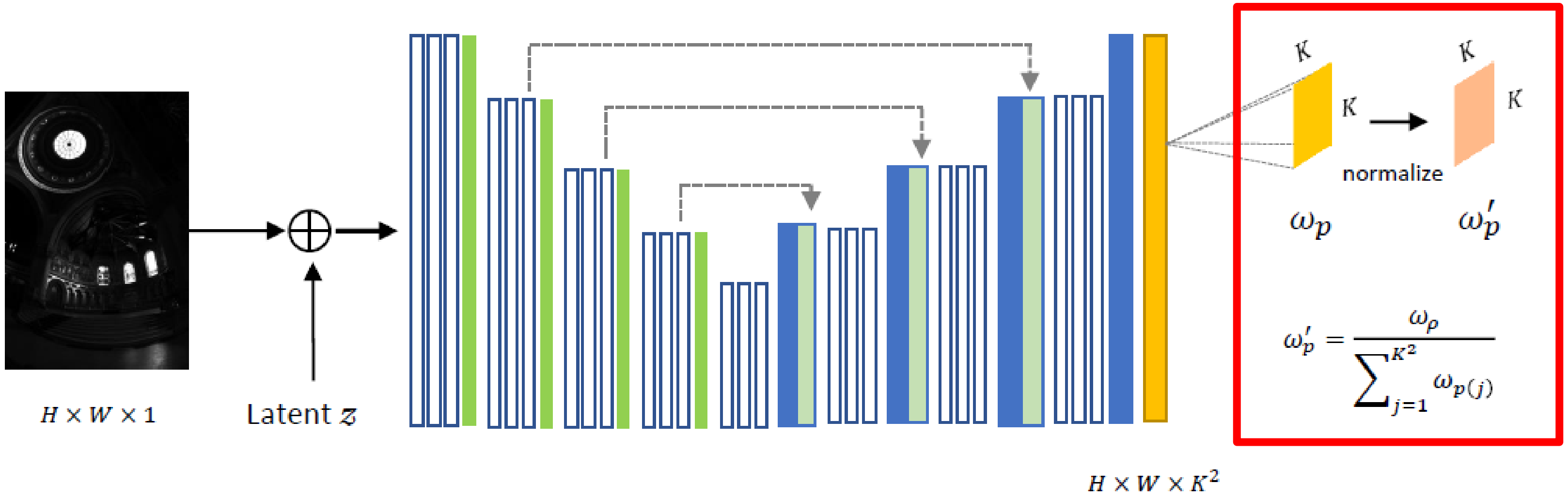
EdgePreservingNet



The EdgePreservingNet is a kernel prediction network [4], which is used to decompose HDR images into base images and detail images.

[4] B. Mildenhall, J. T. Barron, J. Chen, D. Sharlet, R. Ng, R. Carroll, "Burst Denoising with Kernel Prediction Networks" Dec 2017

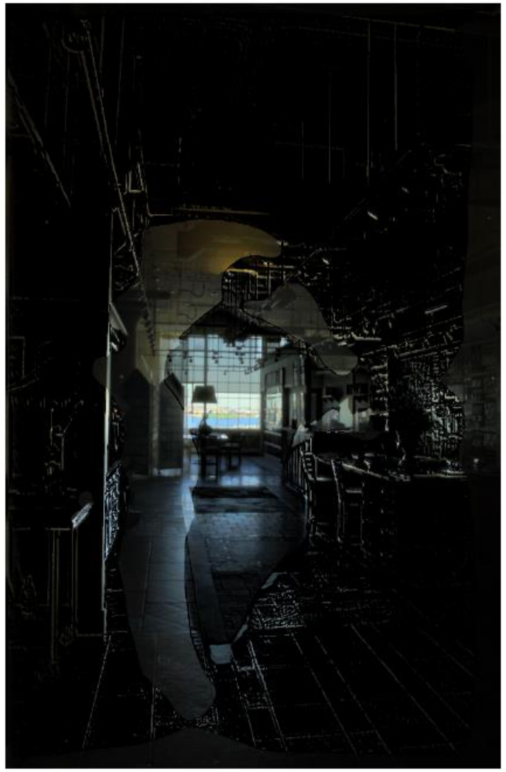
EdgePreservingNet



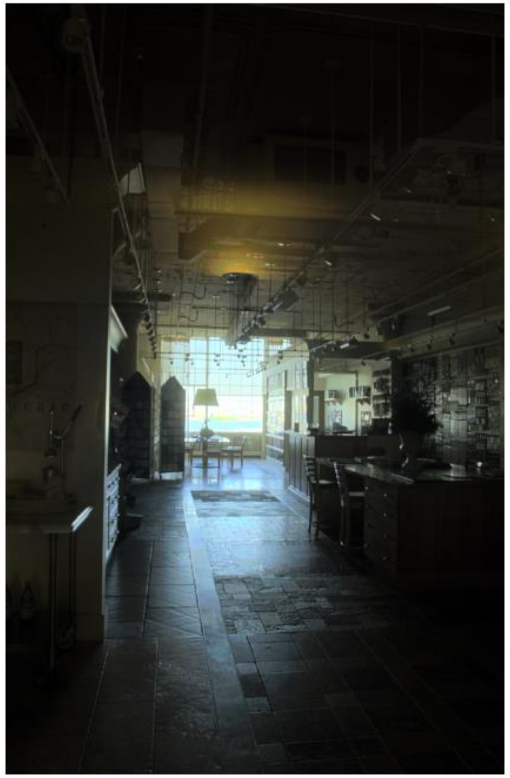
The predicted kernel is normalized to ensure the consistency of image tone.

[4] B. Mildenhall, J. T. Barron, J. Chen, D. Sharlet, R. Ng, R. Carroll, "Burst Denoising with Kernel Prediction Networks" Dec 2017

EdgePreservingNet



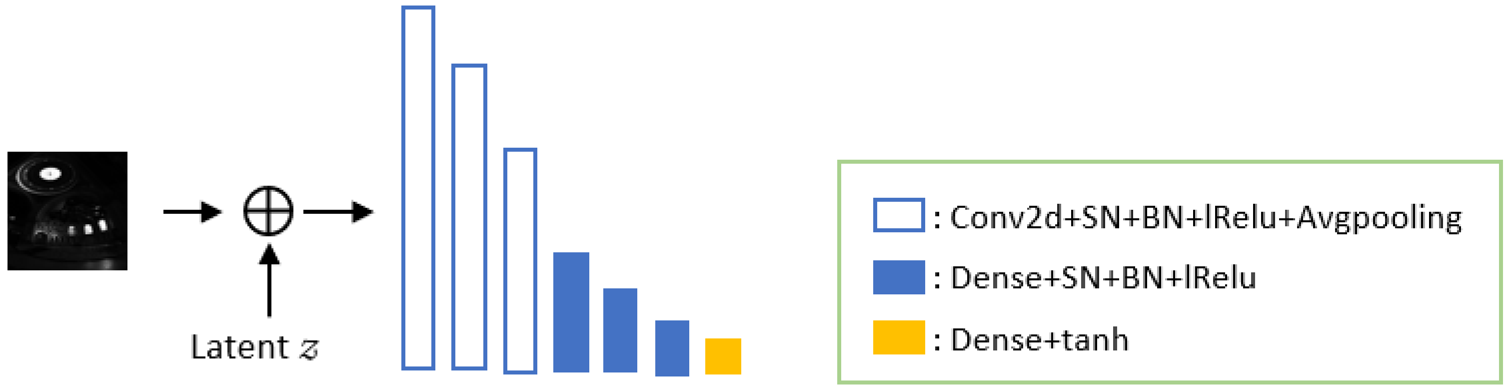
W/o normalization



W/ normalization

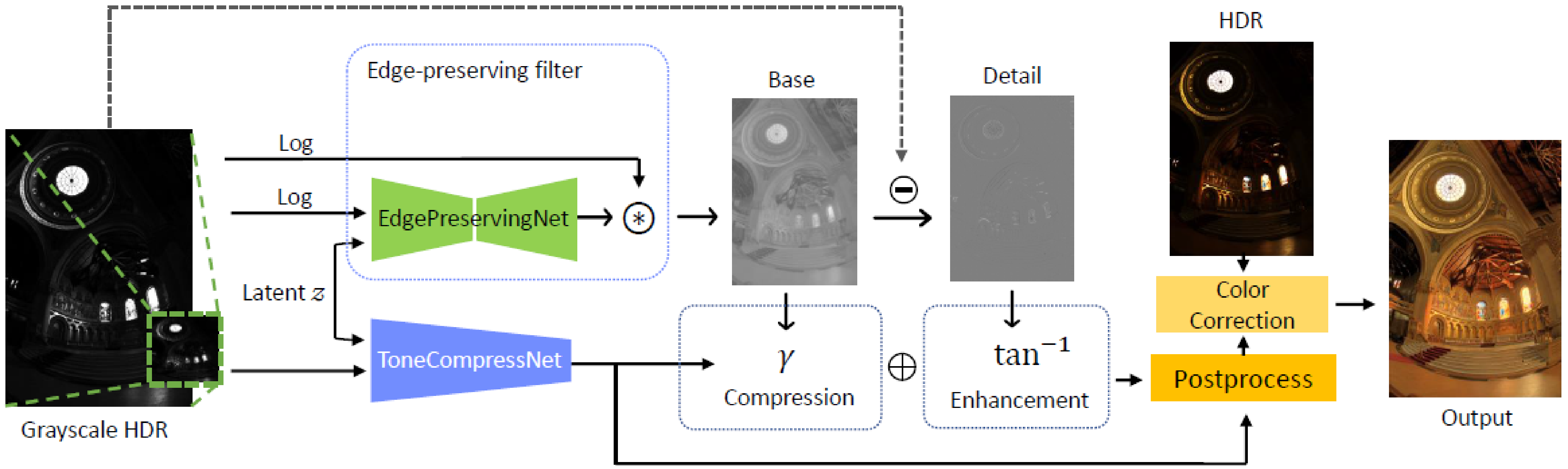
This figure shows that the normalization is critical to the tone-mapping performance.

ToneCompressNet



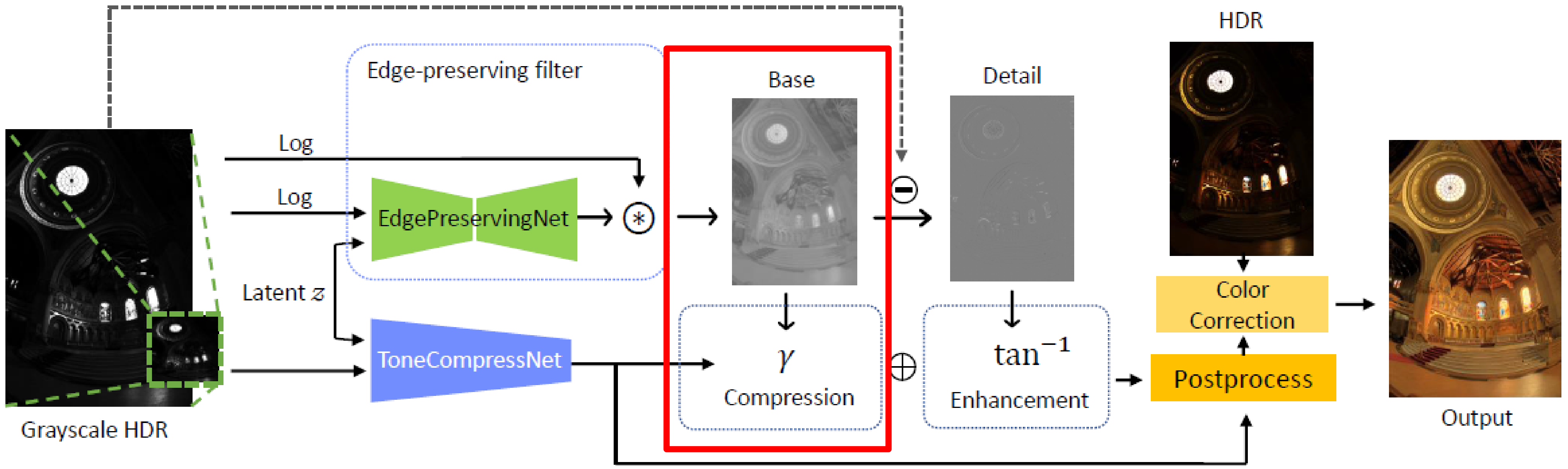
The ToneCompressNet estimates the global tone curve, which is used to compress the base image.

The generator pipeline



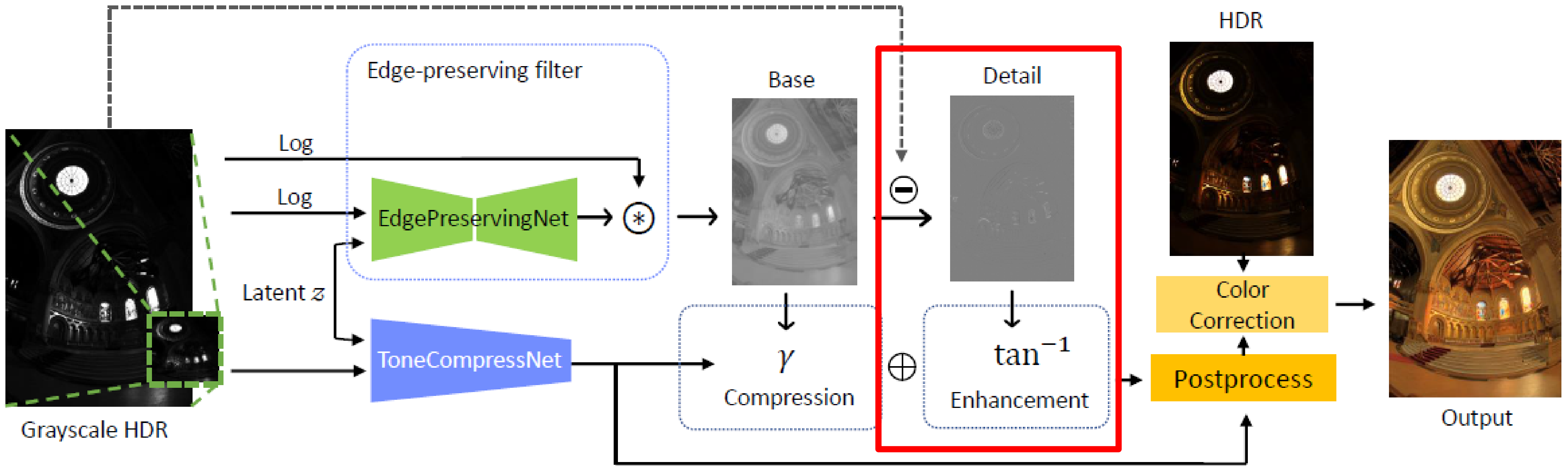
Let's get back to the generator pipeline.

The generator pipeline



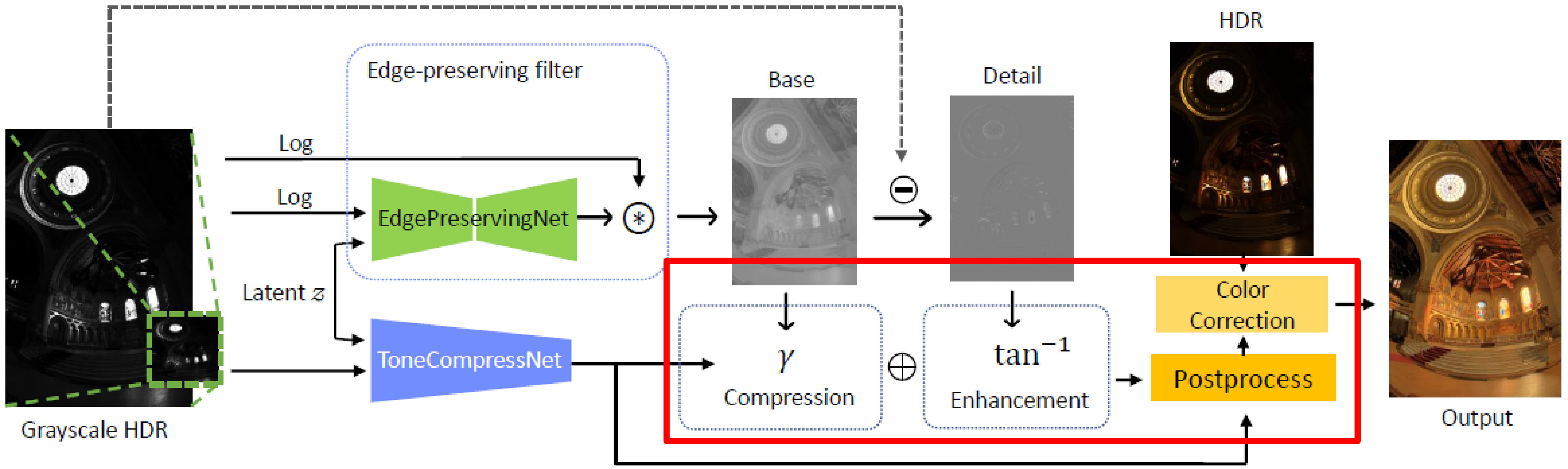
The compressed base image is obtained by the predicted kernels and the global tone curve.

The generator pipeline



The enhanced detail image is acquired by performing a subtraction and an enhancement operation.

The generator pipeline



We then get the LDR image by adding these two images along with some post-processing and color correction operations.

Example of learned decomposed images

(a) Radiance map (b) Our result (c) Learned detail (d) Learned base

This figure shows an example of learned decomposed images.

Experiments

Training Dataset

- We collect HDR images from multiple public sources
- 1032 HDR images with a wide range of contents
  - Scenes
  - Cameras
  - Shooting settings
- Total 3096 HDR-LDR image pairs for training
  - Use Luminance HDR[5] with the default parameters to generate LDR images
  - For each HDR image, the LDR images with top-3 highest TMQI[6] scores are selected as the target images

We collect a dataset from multiple public sources to train our models.

[5] http://qtpfsgui.sourceforge.net/ *[6] H. Yeganeh and Z. Wang, "Objective quality assessment of tone-mapped images," Oct 2013.*

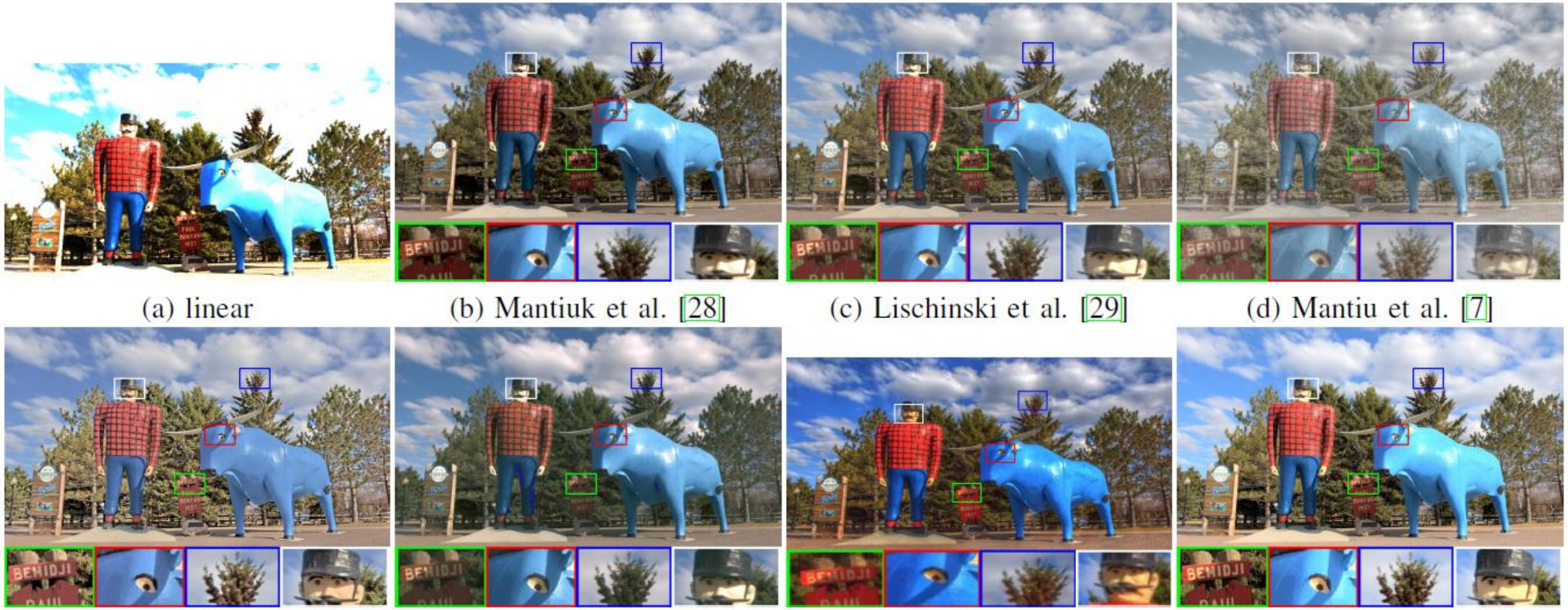
Test Dataset

- **Fairchild's dataset**[7]
  - 105 HDR images
  - Diverse scenes (indoor, outdoor, daylight, night views)

We evaluate our method on the whole Fairchild's dataset of the original resolution (about 4k).

[7] http://rit-mcsl.org/fairchild/HDR.html.

Visual Results


(a) linear (b) Mantiuk et al. [28] (c) Lischinski et al. [29] (d) Mantiu et al. [7]
(e) Liang et al. [6] (f) Yang et al. [8] (g) *Rana et al. [9] (h) Ours

This figure shows that our results preserve the detail of input HDR images without halo artifacts or over enhancement. The color appearance of our results are also visually appealing.

Diversity in Different Latent Codes

(a) Input radiance map

(b) Various tone-mapped results by linearly interpolated latent codes.

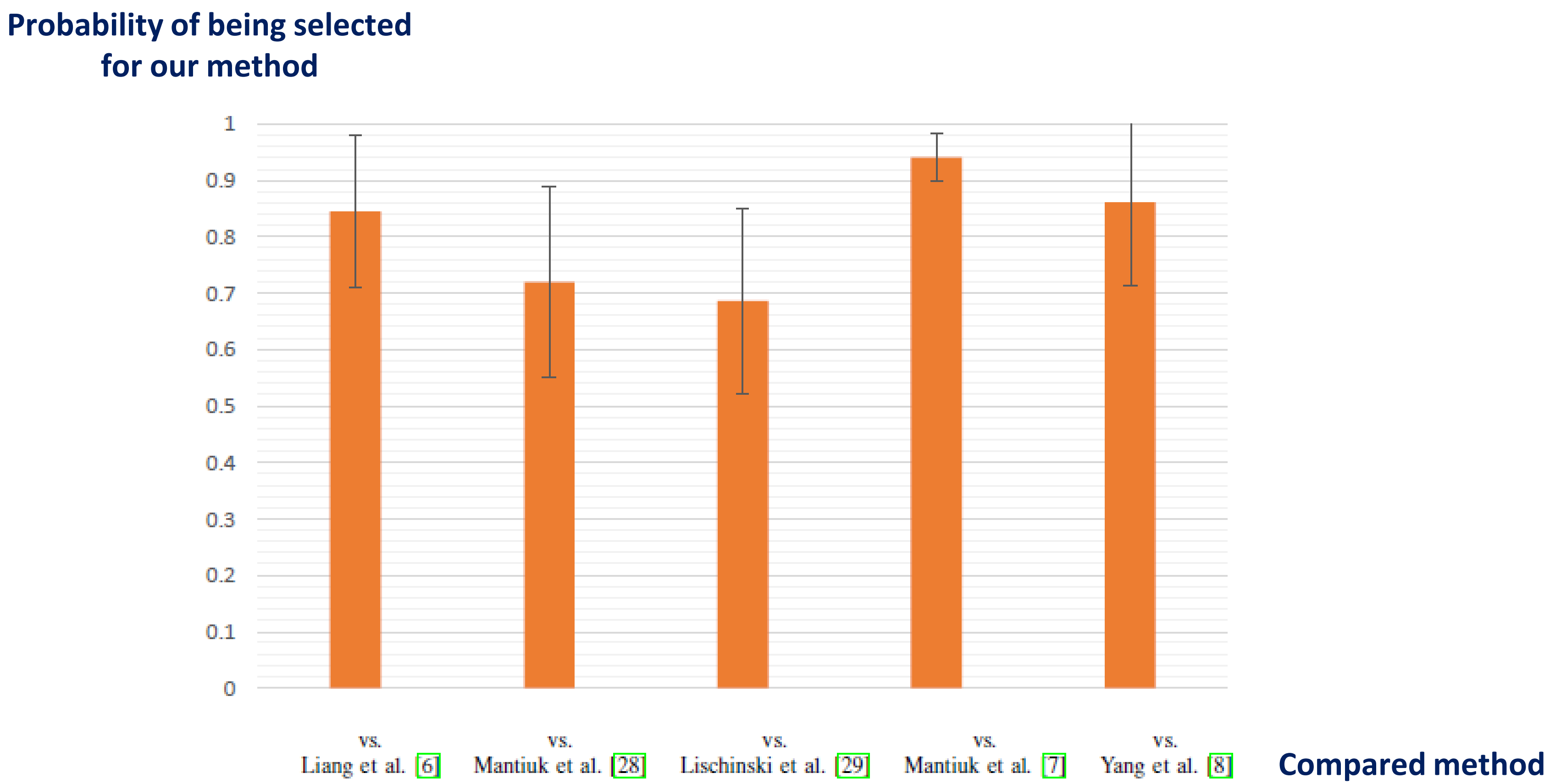
This figure shows the linearity of our results with respect to latent codes.

Quantitative Results

Methods	TMQI	Fidelity	Naturalness
Drago et al. [41]	0.8030	0.7777	0.2289
Fattal et al. [4]	0.8126	0.8217	0.2220
Durand et al. [3]	0.8211	0.7943	0.2993
Mai et al. [42]	0.8184	0.8077	0.2554
Reinhard et al. [5]	0.8282	0.7964	0.3281
Mantiuk 08 et al. [28]	0.8447	0.8336	0.3496
Lischinski et al. [29]	0.8564	0.8381	0.4110
Mantiuk 06 et al. [7]	0.8574	**0.8797**	0.3412
Liang et al. [6]	0.8650	0.8074	0.5024
Yang et al. [8]	0.8465	0.7564	0.4793
Ours	**0.8652**	0.8064	**0.5096**

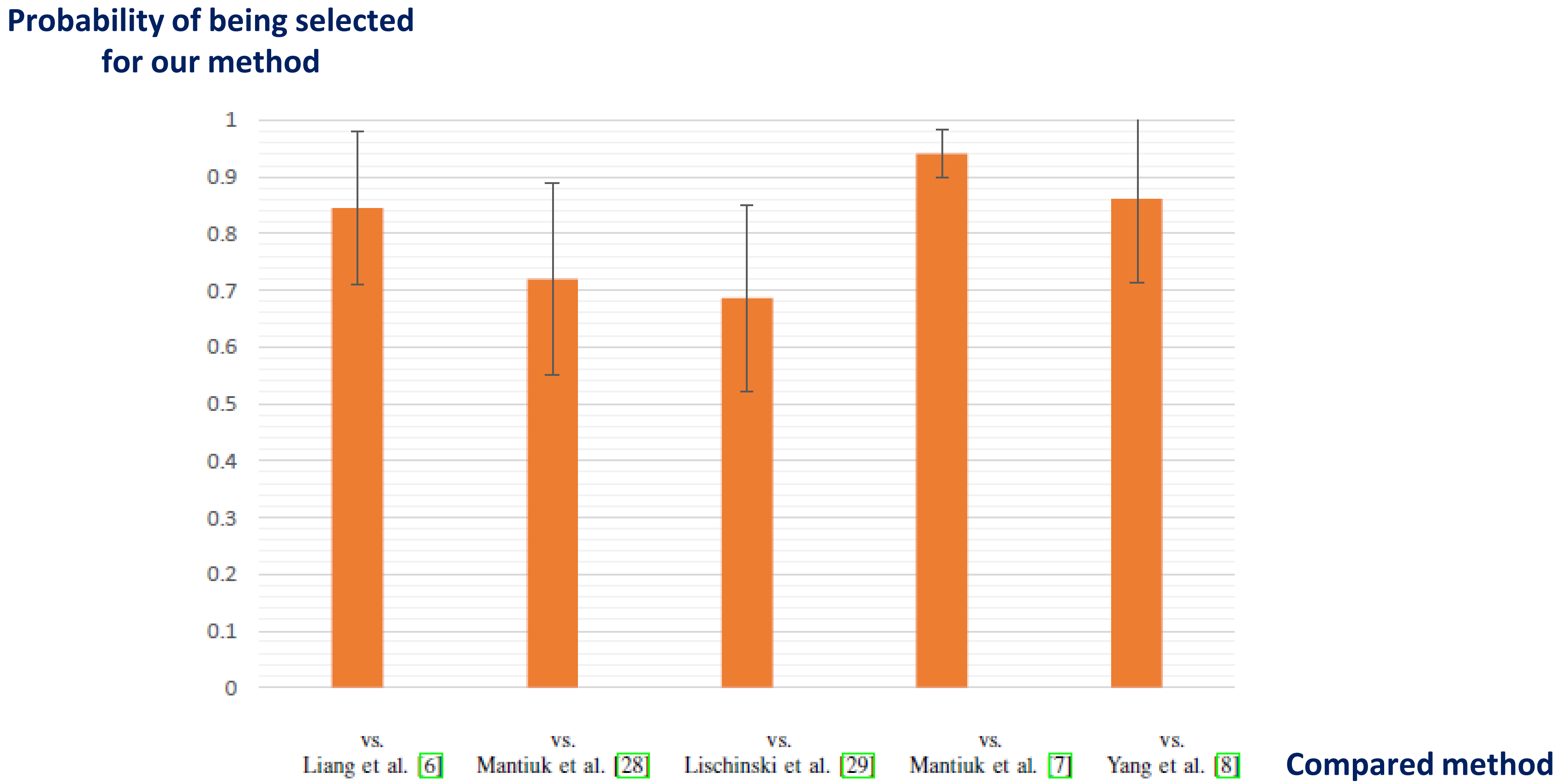
This table shows that our method performs competitively against existing tone mapping algorithms.

User Study



We conduct a user study to further verify the performance of our method.
Totally, 40 subjects are involved in this test.

User Study



The result shows that our method achieves higher probability than the compared methods.

Conclusions

Contributions

Our contributions are summarized as follows:

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1. **Propose a deep learning-based tone-mapping method, which consists of an EdgePreservingNet and a ToneCompressNet.**

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Contributions

1. **Propose a deep learning-based tone-mapping method, which consists of an EdgePreservingNet and a ToneCompressNet.**
2. **By integrating BicycleGAN architecture, our method is able to generate various tone-mapped results from a single HDR image.**
3. **By leveraging bilateral filters, our method compresses the most part of dynamic range while preserves the high-frequency information of HDR images**

Contributions

1. Propose a deep learning-based tone-mapping method, which consists of an EdgePreservingNet and a ToneCompressNet.
2. By integrating BicycleGAN architecture, our method is able to generate various tone-mapped results from a single HDR image.
3. By leveraging bilateral filters, our method compresses the most part of dynamic range while preserves the high-frequency information of HDR images
4. Our method performs favorably against existing methods in terms of both subjective and objective evaluations.

Thanks for your attention!