Photorealistic Image Stylization Using Closed-Form Solutions

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1 abstract

Photorealistic image stylization aims to transfer the style of a reference image to a content image while preserving photorealism. In this project, we implement a closed-form solution involving a two-step stylization and smoothing approach based on the FastPhotoStyle pipeline. We show that our system generates high-quality, photorealistic results with significantly fewer artifacts and faster runtime than existing state-of-the-art methods.

2 Introduction

Photorealistic image stylization is the task of applying the style of a reference photo to a content photo while ensuring that the result maintains photorealism. Applications of this technique include seasonal transformation (e.g., summer to winter), time-of-day transfer, and video color grading.

Earlier stylization techniques focused on color histogram matching or optimization-based style transfer but often produced spatial inconsistencies or structural artifacts. The neural style transfer algorithm introduced by Gatys et al. achieved artistic results but lacked photorealism. More recent approaches such as Deep Photo Style Transfer (Luan et al.) added photorealism constraints but at the cost of computational efficiency.

Our approach builds on the FastPhotoStyle method, which integrates a stylization step (PhotoWCT) and a smoothing step with closed-form solutions, allowing fast and accurate stylization.

3 Approach

Our method includes two stages:

1. **Stylization via PhotoWCT:** We use a whitening and coloring transform (WCT) applied to VGG-19 feature maps for style transfer. We enhance it with unpooling operations to preserve spatial information and reduce artifacts.

2. **Smoothing via Manifold Ranking:** A graph-based smoothing step ensures consistent stylization across semantically similar regions. It uses a matting affinity matrix derived from the content image and solves a linear system with a closed-form solution.

We used the pre-trained VGG-19 encoder and trained symmetric decoders. The multi-level stylization applies WCT at multiple VGG layers to preserve both global and local style features.

4 Experiments and Results

We evaluated our approach on 25 content-style pairs. The experiments were conducted using images resized to 1024x512 pixels. We compared our method with classical (Reinhard, Pitié), artistic (Gatys, Huang), and neural (Luan et al.) methods.

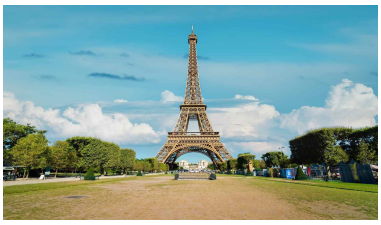
Metrics:

- **Photorealism:** Judged via Amazon Mechanical Turk (AMT) user study.
- **Structural Preservation:** Evaluated using edge detection similarity (ODS, OIS) with HED detector.
- **Runtime:** Measured on an NVIDIA RTX 3070 GPU.

Findings:

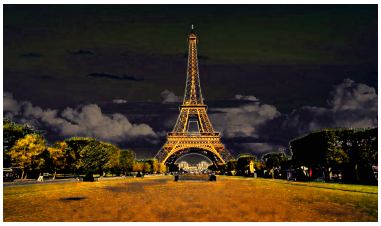
- Our method achieved 73.5% user preference for photorealism over Luan et al.
- Stylization quality was preferred 63.1% of the time.
- Our method ran 49x faster than Luan et al. for 1024x512 images.

4.1 Results



I_C (Eiffel)

I_S (Big Ben)



$I_C + I_S$ (Big Ben styled Eiffel tower)

Figure 1: First Example

I_C (Japan Forest)

I_S (Amazon Forest)

$I_C + I_S$ (Amazon styled Japan forest)

Figure 2: Second Example

I_C (Pyramids of Giza)

I_S (Pyramids of Maya)

$I_C + I_S$ (Maya styled Pyramids of Giza)

Figure 3: Third Example

5 Qualitative Results

Failure cases include pattern transfer where style elements (e.g., flower prints) cannot be synthesized due to pixel-level affinity assumptions.

6 Conclusion and Future Work

We implemented an efficient and effective photorealistic image stylization pipeline. Our method combines style fidelity with structural preservation, using only closed-form computations. Future work includes enhancing pattern transfer, incorporating GANs for structure-aware refinement, and extending to video stylization.

References

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