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End-to-End Alternating Optimization for Real-World Blind Super Resolution

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Abstract

Blind super-resolution (SR) usually involves two sub-problems: (1) estimating the degradation of the given low-resolution (LR) image; (2) super-resolving the LR image to its high-resolution (HR) counterpart. Both problems are ill-posed due to the information loss in the degrading process. Most previous methods try to solve the two problems independently, but often fall into a dilemma: a good super-resolved HR result requires an accurate degradation estimation, which however, is difficult to be obtained without the help of original HR information. To address this issue, instead of considering these two problems independently, we adopt an alternating optimization algorithm, which can estimate the degradation and restore the SR image in a single model. Specifically, we design two convolutional neural modules, namely *Restorer* and *Estimator*. *Restorer* restores the SR image based on the estimated degradation, and *Estimator* estimates the degradation with the help of the restored SR image. We alternate these two modules repeatedly and unfold this process to form an end-to-end trainable network. In this way, both *Restorer* and *Estimator* could get benefited from the intermediate results of each other, and make each sub-problem easier. Moreover, *Restorer* and *Estimator* are optimized in an end-to-end manner, thus they could get more tolerant of the estimation deviations of each other and cooperate better to achieve more robust and accurate final results. Extensive experiments on both synthetic datasets and real-world images show that the proposed method can largely outperform state-of-the-art methods and produce more visually favorable results.

Keywords Blind super resolution · Degradation estimation · Alternating optimization · *Restorer*, *Estimator*

1 Introduction

Single image super-resolution (SR) aims to recover the high-resolution (HR) version of a given degraded low-resolution (LR) image. It has wide applications in video enhancement, medical imaging, as well as security and surveillance imaging. Generally, the degradation process can be formulated as

$$\mathbf{y} = [(\mathbf{x} \otimes \mathbf{k}) \downarrow_s + \mathbf{n}]_q \tag{1}$$

where $\mathbf{x}$ is the original HR image, $\mathbf{y}$ is the degraded LR image, $\otimes$ denotes the two-dimensional convolution of $\mathbf{x}$ with blur kernel $\mathbf{k}$, $\mathbf{n}$ denotes the random noise, $\downarrow_s$ denotes the standard s-fold downsampler (keeping only the upper-left pixel for each distinct $s \times s$ patch) (Zhang et al., 2020), and $[\cdot]_q$ denotes JPEG compression with quality factor q. Then SR refers to

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