Deep Learning for Seeing Through Window With Raindrops

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Abstract

When taking pictures through glass window in rainy day, the images are comprised and corrupted by the raindrops adhered to glass surfaces. It is a challenging problem to remove the effect of raindrops from an image. The key task is how to accurately and robustly identify the raindrop regions in an image. This paper develops a convolutional neural network (CNN) for removing the effect of raindrops from an image. In the proposed CNN, we introduce a double attention mechanism that concurrently guides the CNN using shape-driven attention and channel re-calibration. The shape-driven attention exploits physical shape priors of raindrops, i.e. *convexness and contour closedness, to accurately locate raindrops, and the channel re-calibration improves the robustness when processing raindrops with varying appearances. The experimental results show that the proposed CNN outperforms the state-of-the-art approaches in terms of both quantitative metrics and visual quality.*

1. Introduction

In rainy weather, there are many situations that one need to take pictures of outside scenes through glass windows or window shields. As the glass window is covered by raindrops in such scenarios, the captured images are comprised by the effect caused by these raindrops. The same phenomenon happens when camera lens are covered by raindrops when taking pictures outdoor in rainy day. The effect of raindrops on an image can significantly degrade its visibility. See Fig. 1 for the illustration of real images taken through windows with raindrops. In addition to visual quality degradation, the raindrops also have negative impacts on the performance of outdoor computer vision systems, particularly the ones used in safety driving, outdoor surveillance, intelligent vehicle systems and camera drones; see *e.g.* [12, 23]. There is certainly a need for developing computational methods that can effectively remove raindrops from an image, *i.e.* restore the visual distortions caused by the raindrops on images.

The optical model of an image taken through window with raindrops is quite complex. For our purpose, we consider a simple linear model [23]:

$$\boldsymbol{I} = (1 - \boldsymbol{A}) \odot \boldsymbol{L} + \boldsymbol{A} \odot \boldsymbol{R}, \quad (1)$$

where $\odot$ denotes element-wise multiplication, $\boldsymbol{I}, \boldsymbol{L}, \boldsymbol{R} \in \mathbb{R}^{C\times M\times N}$ denote the image with raindrops, the latent raindrop-free layer, and the raindrop layer respectively. The matrix $\boldsymbol{A} \in [0,1]^{C\times M\times N}$ denotes the transparency matrix. Each entry of $\boldsymbol{A}$ represents the percentage of the light path covered by raindrops for the corresponding pixel. As the latent image layer $\boldsymbol{L}$ refers to the scene behind the glasses, we also refer to $\boldsymbol{L}$ as background image/layer.

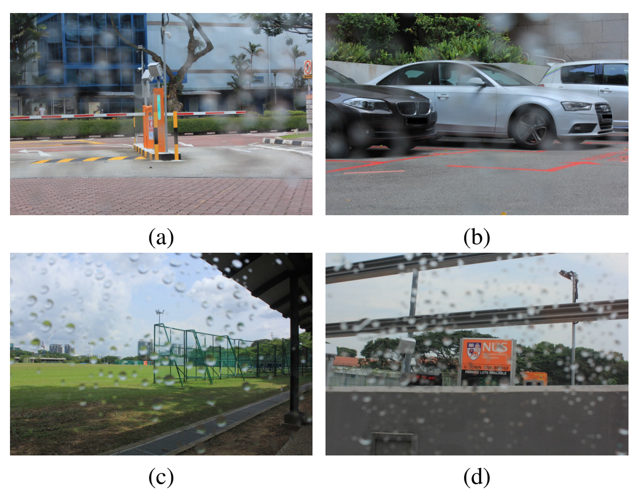

Figure 1: Examples of images taken through windows with raindrops.

Different values of $\boldsymbol{A}$ will lead to different types of vi-

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