# NON-LOCAL SINGLE IMAGE DE-RAINING WITHOUT DECOMPOSITION

Chaobing Zheng [1], Zhengguo Li [2], Li Yuwen[1] and Shiqian Wu[1]
[1]Wuhan University of Science and Technology, China
[2]Institute for Infocomm Research, Singapore

## Motivation:

- Decomposition-based methods distort important details of the underlying features for high-level computer vision task;
- Due to the similarities between the denoising and deraining, ideas of existing nonlocal denoising algorithms can be extended to study single image deraining;
- Non-local self similarity in natural images is a very effective prior information;
- ⟹ A nonlocal de-raining algorithm is proposed in this paper to remove the rain streaks from the rainy image.

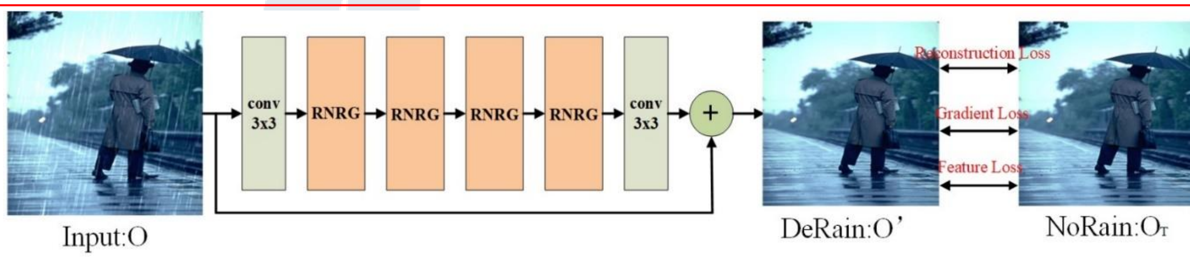


*Fig. 1. The proposed framework for single-image rain removal*

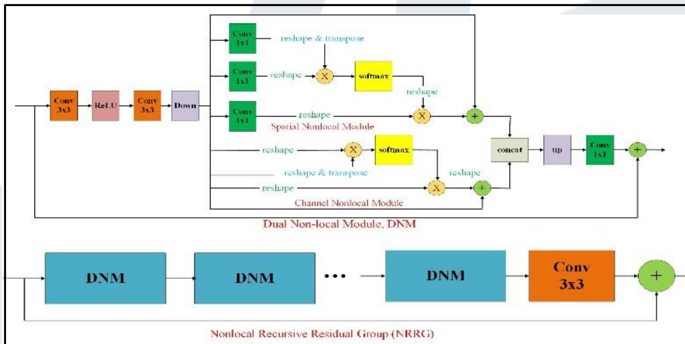


*Fig. 2. The proposed NRRG contains multiple nonlocal DABs*

## Non-local De-raining without Decomposition

**Non-local self similarity** in natural images is a very effective prior information, which has been widely concerned in image restoration.

- **Spatial nonlocal module:** The feature map $X$ is fed it into a convolution layers to generate three new feature maps: $\hat{X}_1^S$ $\hat{X}_2^S$ $\hat{X}_3^S$ the spatial similarity map:

$$S_{ji}^S = \frac{\exp(\hat{X}_{1,i}^S \cdot \hat{X}_{2,j}^S)}{\sum_{i=1}^N \exp(\hat{X}_{1,i}^S \cdot \hat{X}_{2,j}^S)}$$

The nonlocal spatial module is defined as follows:

$$E_j^S = \sum_{i=1}^N (S_{j,i}^S \cdot \hat{X}_{3,i}^S) + X_j$$

- **Channel nonlocal module:** The feature map $X(C \times H \times W)$ is shaped into $R^{C \times N}$, the channel similarity map:

$$S_{ji}^C = \frac{\exp(X_i \cdot X_j)}{\sum_{i=1}^C \exp(X_i \cdot X_j)}$$

the nonlocal channel module is defined as as follows:

$$E_j^C = \sum_{i=1}^C (S_{j,i}^C \cdot X_i) + X_j$$

## Loss Functions

There are three items in the proposed loss function $L$ which is expressed as:

$$L = L_r + w_c L_c + w_f L_f$$

**Reconstruction Loss:**

$$L_r = \frac{1}{N} \sum \| O_T - f(O) \|_2^2$$

**Gradient Loss:**

$$M(O) = \sum_{x,y} \| \nabla O(x,y) \|_2$$

$$L_g = \frac{1}{N} \sum \| M(O_T) - M(f(O)) \|_1$$

**Feature-wise Loss:**

$$L_f = \frac{1}{w_{i,j} h_{i,j}} \sum_{l=1}^{w_{i,j}} \sum_{m=1}^{h_{i,j}} (\phi_{i,j}(O_T)_{l,m} - \phi_{i,j}(f(O))_{l,m})^2$$

## Comparison of Six Different De-raining Algorithms

| | JORD ER | DDN | Syn2 Rel | SPA Net | DDC Net | MSP FN | DCS FN | Our |
|---|---|---|---|---|---|---|---|---|
| SSIM | 0.891 | 0.924 | 0.814 | 0.874 | 0.877 | 0.936 | 0.923 | **0.967** |
| PSNR | 29.41 | 31.97 | 25.16 | 28.77 | 27.17 | 33.52 | 31.33 | **37.06** |


*Fig. 3. Comparison of different de-raining algorithms multiple*