Appendix: Unsupervised Video Deraining with An Event Camera

Jin Wang Wenming Weng Yueyi Zhang* Zhiwei Xiong
University of Science and Technology of China
{jin01wang, wmweng}@mail.ustc.edu.cn, {zhyuey, zwxiong}@ustc.edu.cn

1. Video Demonstration

We provide a supplementary video at https://drive.google.com/file/d/18kk4fCXQnm6VZ6YABe_YeLIhdh3o3thv/view?usp=sharing. We strongly recommend referring to it for the qualitative comparison.

2. Hybrid Camera System

As mentioned in the main paper, the hybrid camera system consists of a conventional camera (iRAYPLE A5031CU815 with a resolution of 640×480 and an 8mm lens), an event camera (Prophesee Gen3S1.1 with a resolution of 640 × 480 and a 25mm lens), and a beam splitter (Thorlabs CCM1-BS013). We provide details of geometric calibration and temporal synchronization between the event camera and conventional camera below.

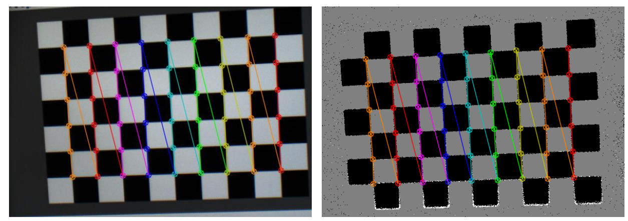
2.1. Geometric Calibration

In geometric calibration, we first display a blinking chessboard pattern with six rows and nine columns on a 27-inch monitor. We place the monitor about one meter away from the hybrid camera system. Frames are captured for conventional cameras at 25fps and we select one frame for subsequent processing and analysis. We accumulate the recorded event stream in the time interval between adjacent frames to form an event image. After obtaining the frame and event image, we use a corner detection algorithm to extract the corners respectively. The detected corners in two camera views are shown in Fig. 1. Some detected corners with inaccurate positions are manually deleted.

Our goal is to geometrically transform pixels in the conventional camera view to the pixels in the event camera view within the shared view. We utilize a homography matrix to model the transformation, based on the detected corners in two camera views. Mathematically, we formulate it as:

$$p_i^E = H \cdot p_i^F, \tag{1}$$

where H denotes a 3×3 transformation matrix, $p_i^E = [x_i^E, y_i^E, 1]^T$ and $p_i^F = [x_i^F, y_i^F, 1]^T$ are the homogeneous coordinates in the accumulated event image and frame. Finally, we warp the frame using the computed matrix H to spatially align two camera views.



RGB camera view Event camera view

Figure 1: The detected corners for homograpy computation from the accumulated event frame and frame.

In our setting, we have

$$H = \begin{bmatrix} 9.5715e{-1} & -8.6694e{-4} & -1.5430e{+1} \\ 2.8549e{-3} & 9.5906e{-1} & 2.5934e{+1} \\ 1.4366e{-6} & 2.4345e{-6} & 1.0000 \end{bmatrix} \tag{2}$$

The computed reprojection rms error is 0.5457 pixel.

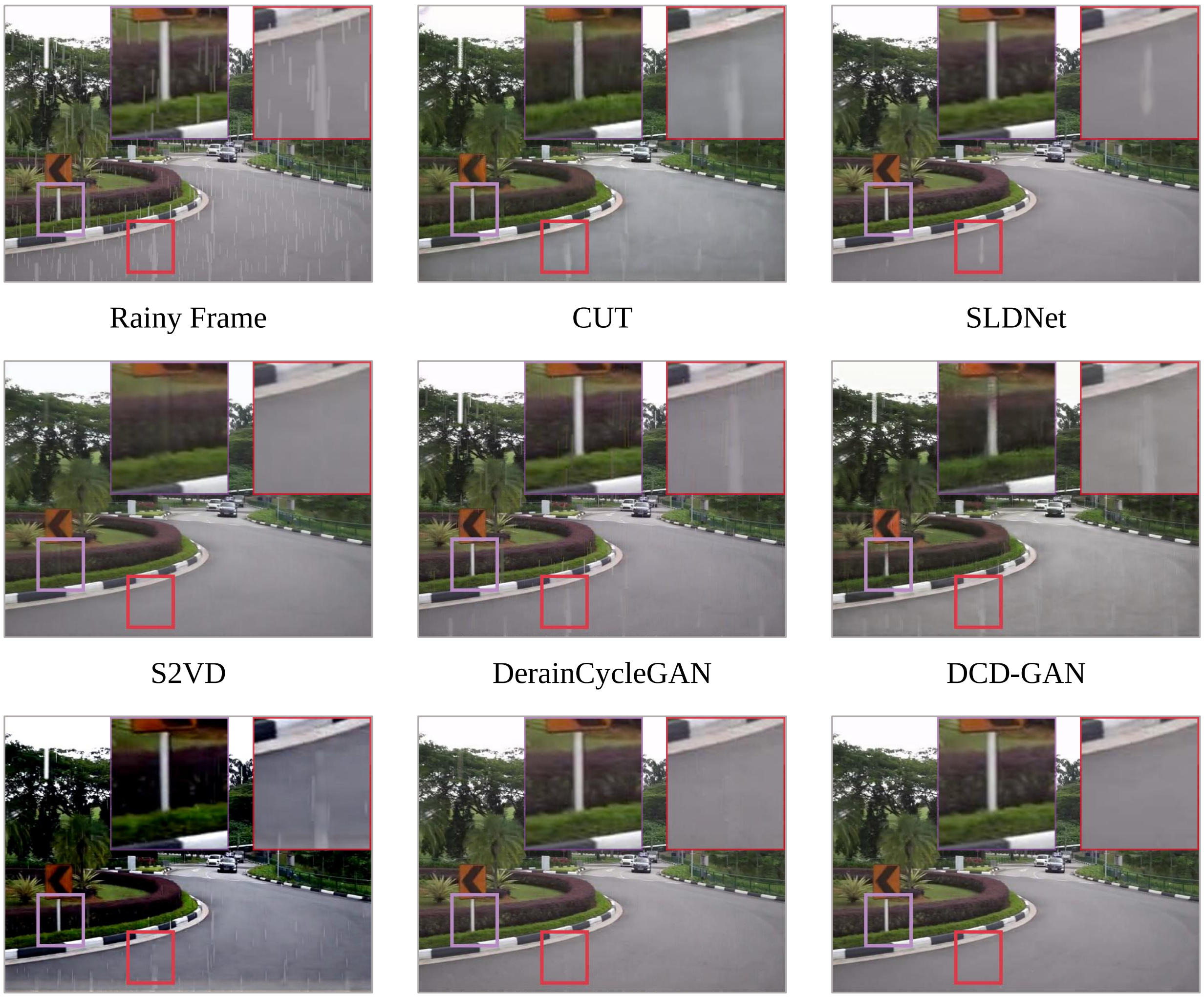
2.2. Temporal Synchronization

In our hybrid camera system, two cameras are temporally synchronized by external triggers. The event camera acts as a master camera and the conventional camera acts as a slave camera. Each time the master event camera starts, the frame sync signal is produced to trigger the conventional camera. The frame rate of the conventional camera is determined by the frequency of the frame sync signal. Finally, we group events during the time interval between consecutive frames to temporally synchronize frame and event data.

3. More Qualitative Results

We present more qualitative comparisons on various datasets, shown in Figs. 2 to 8. It can be observed that our proposed method outperforms other state-of-the-art methods, with best effects of rain removal and detail restoration.

*Corresponding author



Rainy Frame | CUT | SLDNet
S2VD | DerainCycleGAN | DCD-GAN
NLCL | Ours | GT

Figure 2: Qualitative comparisons on the N-NTURain dataset. Zoom-in for better visualization.

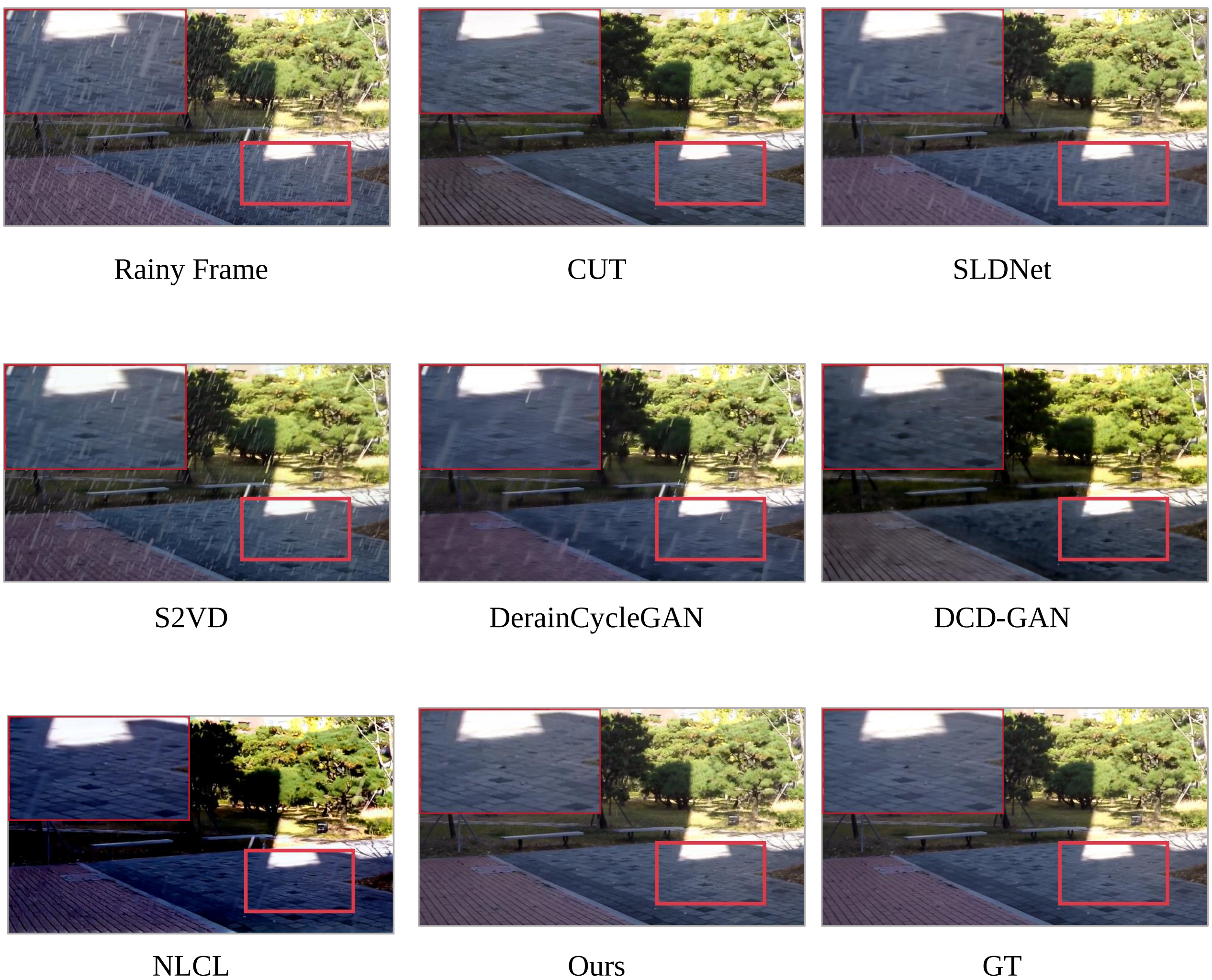


Figure 3: Qualitative comparisons on the N-GoProRain dataset. Zoom-in for better visualization.

Figure 4: Qualitative comparisons on the N-AdobeRainL dataset. Zoom-in for better visualization.

Figure 5: Qualitative comparisons on the N-AdobeRainH dataset. Zoom-in for better visualization.

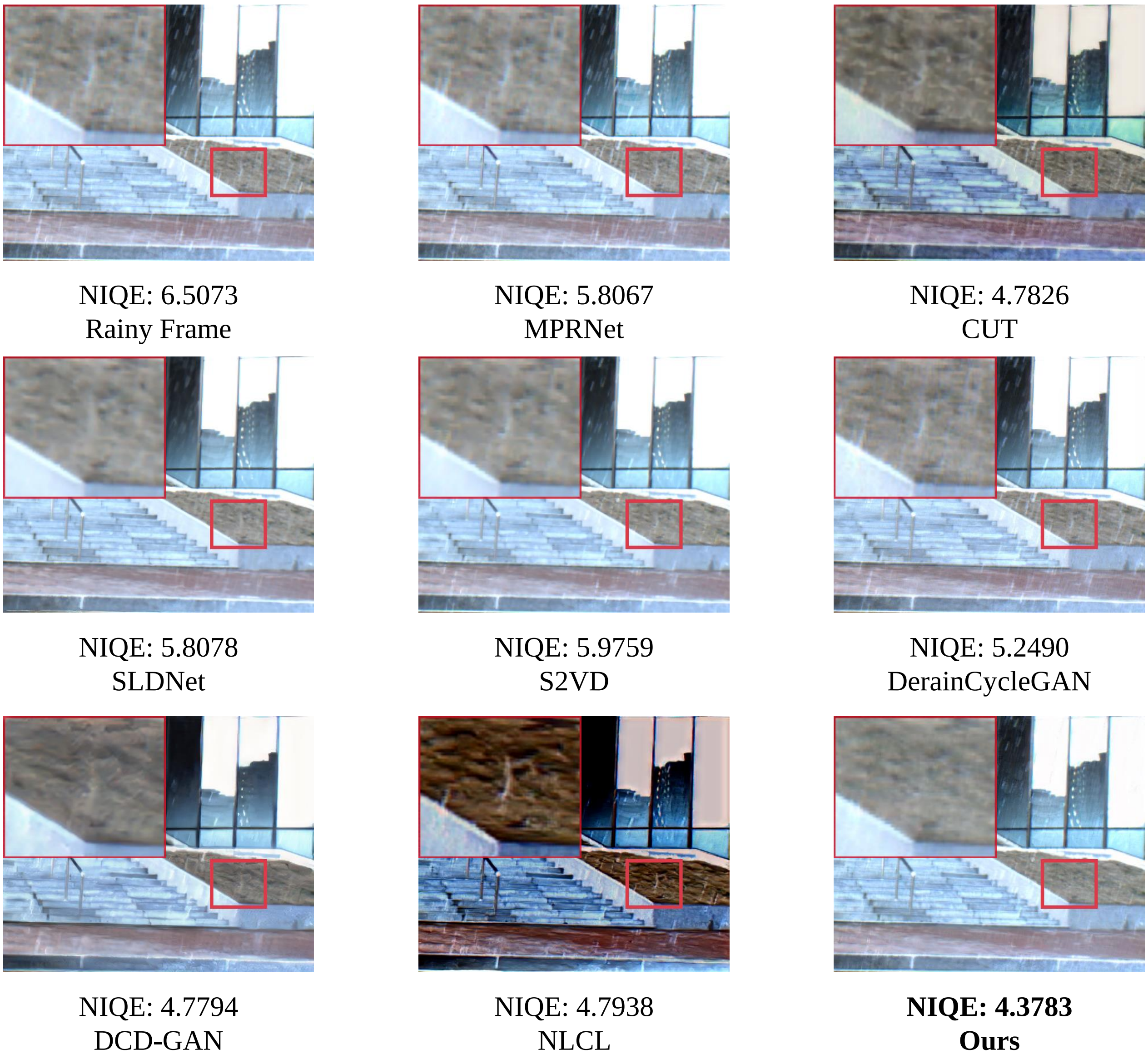


Figure 6: Qualitative comparisons on our real-world dataset RealRain-Event. Zoom-in for better visualization.

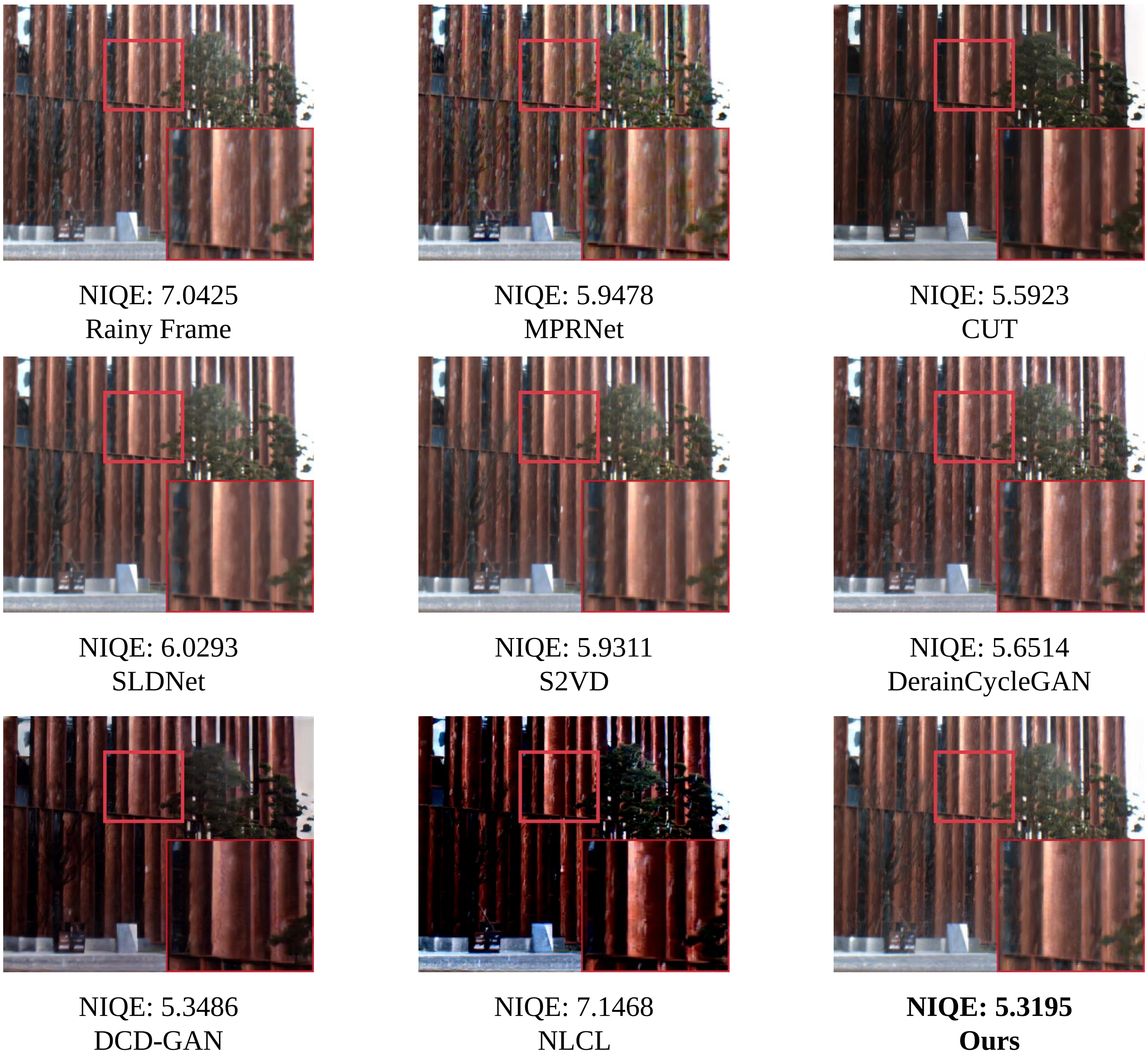


Figure 7: Qualitative comparisons on our real-world dataset RealRain-Event. Zoom-in for better visualization.

Figure 8: Qualitative comparisons on our real-world dataset RealRain-Event. Zoom-in for better visualization.