Image Denoising – white paper

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saiwa

simple artificial intelligence web application

Image Denoising is a sub-category of image restoration which is about restoring clean images by removing a specific kind of distortion: noise. Noise refers to random appearance of undesired traces and variations in the brightness or colour information. Images are inevitably contaminated by noise during acquisition, compression and transmission. The level of noise typically increases with the length of exposure, physical temperature, and sensitivity setting of the camera. Depending on the noise source there are a few types of noises, such as: Gaussian noise, impulse noise, periodic noise and banding noise. Here, we focus on Gaussian noise as a common sensor and electronic circuit noise that may also arise due to poor illumination or high temperature.

Gaussian noise is a random statistical noise having a normal probability density function. Removing Gaussian noise and, in general, image denoising has been studied for a long time; and yet it remains a challenging and open problem because image denoising is an inverse problem, and it therefore does not have one unique solution.

There are a wide range of classic image denoisers that try to model image noise mathematically; and there are also many recent solutions motivated by recent advances in machine learning and deep learning. At saiwa, we provide two image denoising options, one classic and one deep learning based: **Multi-Scale DCT Denoiser** and multi-stage progressive image restoration network (**MPRNet**). Below you will find more technical details of these two image denoisers.

Multi-Scale DCT Denoising is a classic denoising algorithm with low computational complexity [1]. The original DCT denoising algorithm starts by thresholding of a patch-wise Discrete Cousin Transform (DCT) of the noisy input image and then aggregation of the resulting patches. There are variants of DCT denoising. In a successful attempt a two-step multi-scale version is proposed in [1] that enhances the performance of the original method significantly and also reduces halo artifacts in the denoised image. The main advantages of the Multi-Scale DCT denoiser include:

1. A multi-scale version of DCT that keeps all features of its single scale while improving its performance.
2. An extra guide image (or oracle), which is a first denoised image to estimate the empirical Wiener factors of the DCT coefficients in the second step
3. Adaptive patch aggregation that reduces the halo effects around the contrasted image edges

Figure 1 shows a few instances of applying Multi-Scale DCT denoising algorithm to remove noises from images using saiwa Denoising service interface.

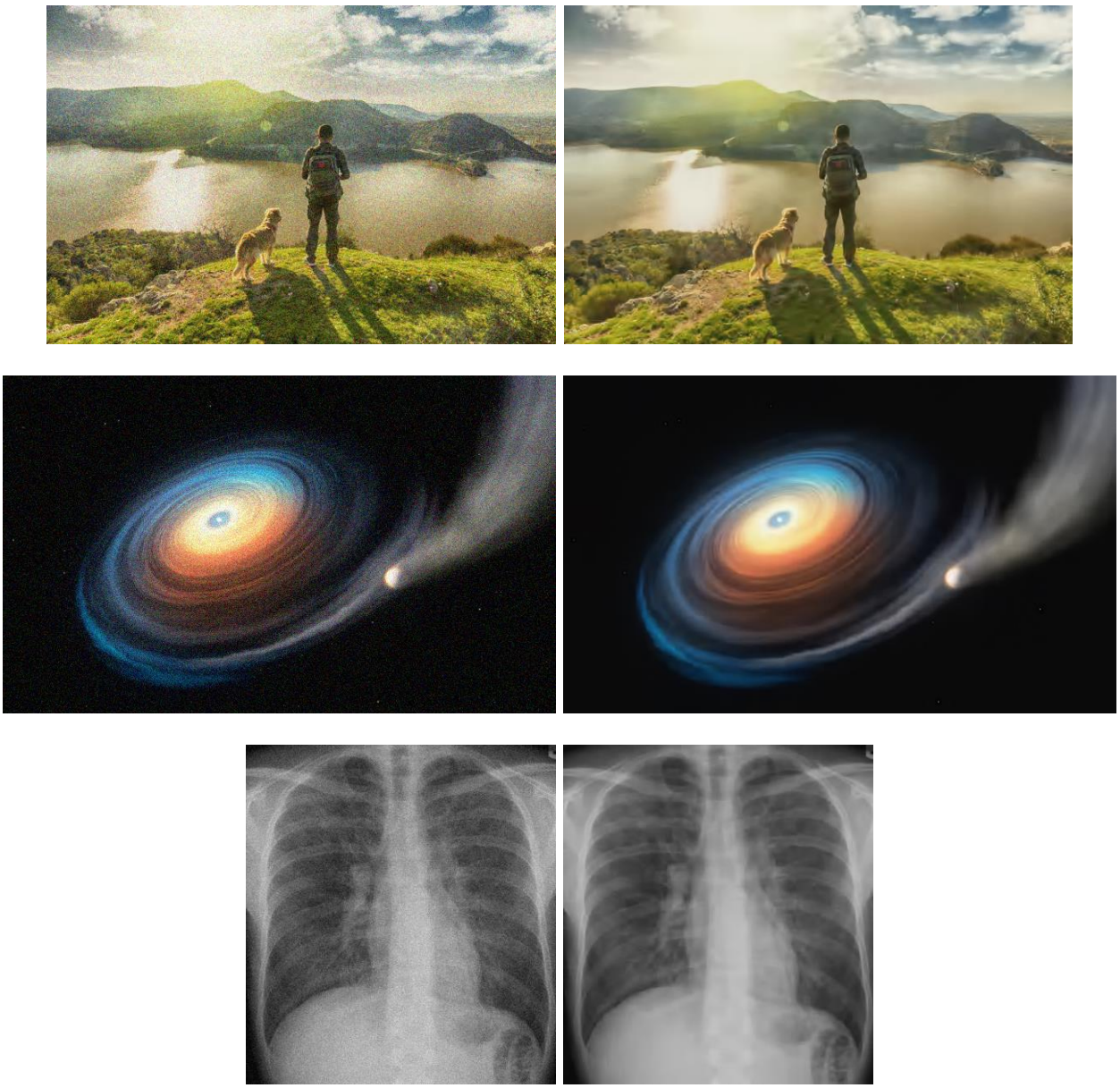

Figure 1. Subjective denoising results of Multi-Scale DCT denoiser method and using saiwa online demo.

The second denoiser provided by saiwa is multi-stage progressive image restoration network (**MPRNet**). MPRNet is a three-stage CNN (convolutional neural network) for image restoration. It has been shown that MPRNet provides high performance gains on several datasets for a range of image restoration problems including image deraining, deblurring, and denoising [2].

The three-stage structure of MPRNet shown in Figure 2 provides several key features:

1. An encoder-decoder for learning multi-scale contextual information in the first two stages
2. Preservation of fine spatial details of the input image by operating on the original image resolution in the last stage
3. A supervised attention module (SAM) that enables progressive learning
4. Cross-stage feature fusion (CSFF) to propagate multi-scale contextualized features from early to late stages.

For more technical details of the MPRNet architecture please refer to [2]. Figure 3 shows a few instances of image denoising using MPRNet method and saiwa Denoising service interface. We use an open-source implementation of MPRNet that is suggested by the original paper [3].

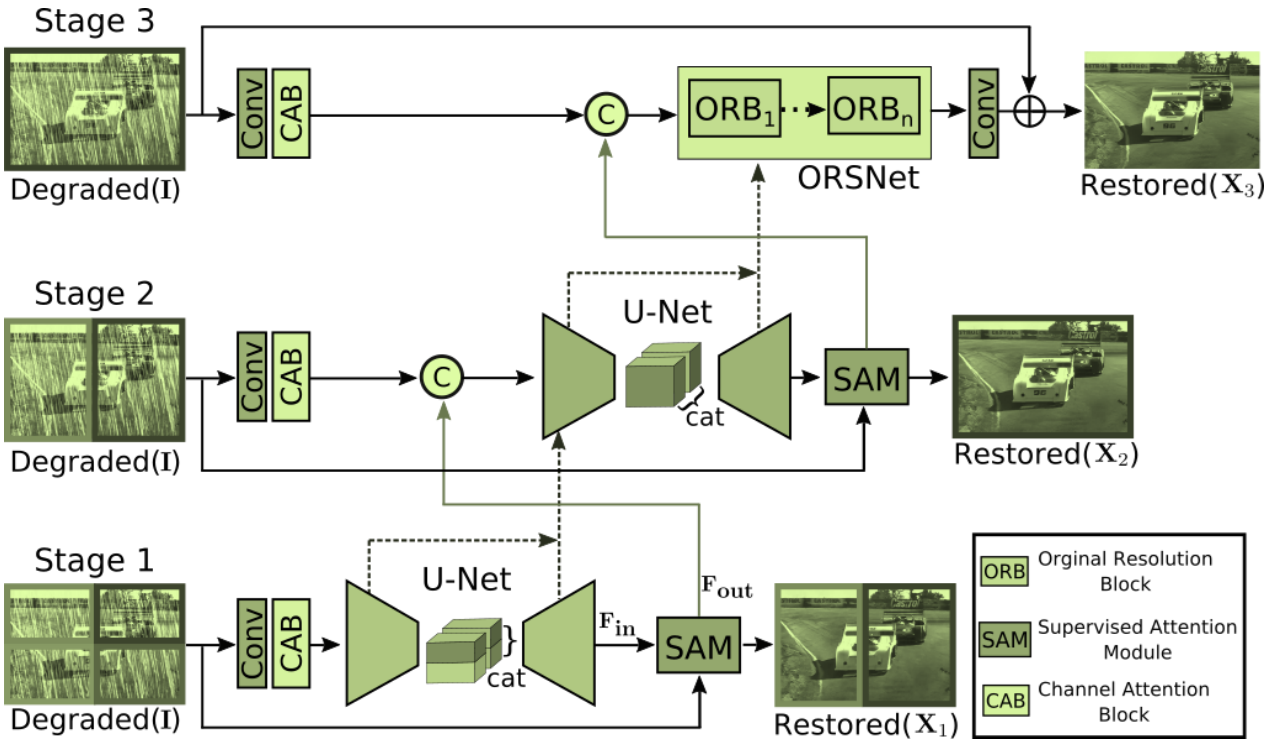

Figure 2. Multi-stage architecture for progressive image restoration of MPRNet (printed from [2])

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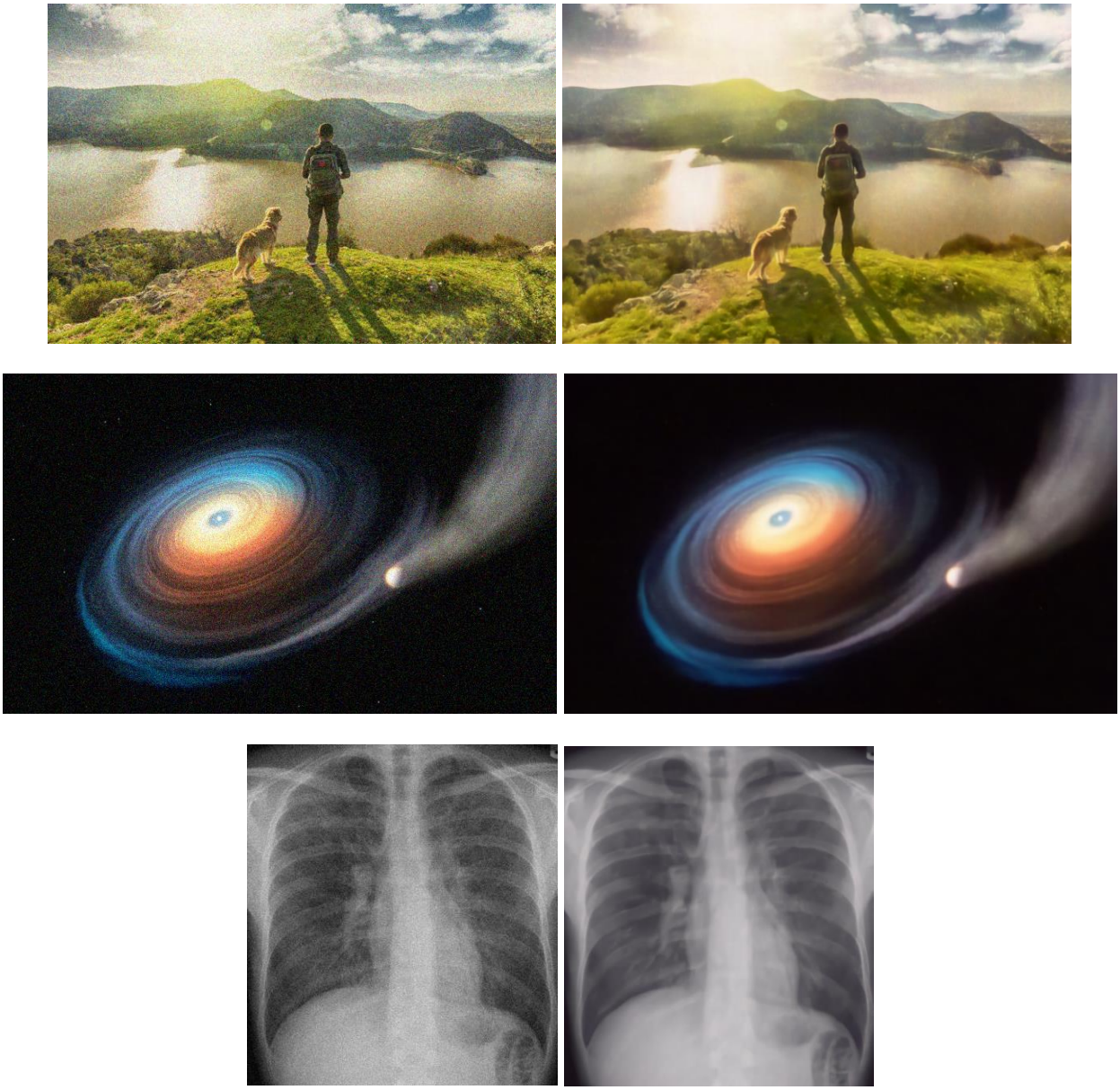

Figure 3. Subjective denoising results of MPRNet denoiser and using saiwa online demo.

References:

[1] Pierazzo, Nicola, Jean-Michel Morel, and Gabriele Facciolo. "Multi-scale DCT denoising." Image Processing On Line 7 (2017): 288-308.

[2] Zamir, Syed Waqas, et al. "Multi-stage progressive image restoration." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2021.

[3] https://github.com/swz30/MPRNet.

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