Paper Reading Report-01

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Abstract

*This is my reading report for the paper titled: "***Learning Deep CNN Denoiser Prior for Image Restoration***", authored by Kai Zhang (Harbin Institute of Technology) et al, and published in CVPR 2017.*

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I, [Shixuan Liu], hereby confirm that I am the sole author of this report and that I have compiled it in my own words.

1. Problem Statement

The research problem is about to address the problem in image restoration field, which aims to recover a clear figure from the original image by degraded model $y = Hx + v$, where H is the degraded matrix and v is the noise. Generally speaking, we can solve equation 1 to solve the problem and there are two kinds of methods, model-based optimization method and discriminative learning method [1].

$$\hat{x} = \text{argmin}_x \frac{1}{2}||\mathbf{y} - \mathbf{Hx}||^2 + \lambda\phi(x) \tag{1}$$

The advantage of model-based optimization method is flexible, while the discriminative learning method has the high performance and be fast to test on the dataset. Although it exists the methods combining the advantages of these two methods, the further study is still needed. And this paper aims to do further research on this problem. I think this research is meaningful. Combining discriminative learning methods with model-based methods can quickly and flexibly solve image deblurring and other related problems, which is a further improvement and optimization of image restoration tasks.

The current state of the art is using two variational autoencoders to convert clean photos and old photos into latent vector space respectively and the two latent spaces learn from each other to improve the performance of image restoration [2]

The author aims to combine the discriminative denoisers with model-based method. For this paper, the goal is using Covolutional Neural Network rather than MAP inference to train discriminative denoising factors and insert the trained denoisers into model-based optimization methods. The niche of this paper is that the authors hope to combine the advantages of CNN for many years to improve the image denoising problem and insert the denoiser into the model-based optimization method to improve the performance of image restoration.

2. Summarise the paper's main contributions

1. Train a set of denoisers based on the CNN model.
2. Insert The CNN denoiser into the model-based optimization methods. The fast and flexible advantages of CNN denoiser have been proved in a large number of experiments.

I think the author is a bit over-claiming in the design of the CNN denoiser. In general, the author uses past experimental experience and discoveries to modify the CNN model. I don't think there is much contribution here.

3. Method and Experiment

The most important contribution of this paper is to use CNN to learn the noise term in formula 1. And use the denoiser to solve the image denoising problem. The denoising model uses seven convolutional layers and three blocks. In the paper, the model mainly has four contributions of the denoising problem.

1. **Use Filter to Enhance the Receptive Field**. In the denoising problem, the context background information of the image has a lot of influence on the restoration tasks. So this article uses the method of dilated convolution to balance the size of the receptive field and the depth of the convolution layers to obtain more context pixel information.
2. **Use Residual Learning and Batch Normalization Layer**. The author believes that the residual structure and the BN layer can promote each other to remove Gaussian noise.

3. **Reduce sample size to reduce boundary artifacts**. Based on the experience, the author found that smaller training samples could enhance the ability of the CNN model to construct the image boundary. Therefore, the image is cropped into multiple non-overlapping small blocks to enhance the boundary information.

4. **Learn in the small noise interval**. Other researches have shown that in the process of solving Equation 1, using inaccurate sub-problems can speed up the convergence [3]. Therefore, the author uses a set of denoisers to deal with the noise of different noise intervals.

The author considers that the denoising of color images needs to combine the performance of denoising model and considering the connection of three pixel channels. In addition, CNN has developed rapidly in recent years. Therefore, they finally uses the CNN model to discriminatively denoise.

The author evaluates the model on three tasks, Image Denoising, Image Deblurring and Single Image Super-Resolution. Compared with other models, the author's model can give full play to its advantages, that is, having better performance than traditional model-based optimization and more flexible than discriminative learning methods.

4. Critical Analysis

4.1. Are the paper's contributions significant?

I think the author's contribution is incremental. They combined the traditional image denoising method with the deep learning-based image denoising method and gave full play to their respective advantages. However, the disadvantage of innovation is that the CNN-based method does not propose many innovations. The main method is to borrow existing experience to improve the denoiser and insert it into traditional solutions. Since the final effect is good enough and it is a combination method that did not occur before, I still think the author has made a contribution.

4.2. Are the authors' main claims valid?

In my opinion, the author team used a lot of experiments to prove the advantages of the model, and made a lot of explanations about it. Therefore, these experiments are convincing and effective.

4.3. Limitation and weaknesses

As I said before, they did not make many improvements in the discriminative learning method. This is more like a combination of two techniques and an experiment to prove its effectiveness.

4.4. Extension and future work

I think that whether it is in the discriminative learning method or the model-based optimization method, it will be very good to find more innovative methods or technologies in combination with the image restoration problem. For example, in addition to the residual structure, some other structures (such as Dense Blocks) can be used to enhance contextual information.

4.5. Is the paper stimulating or inspiring ?

I think this paper is a bit inspiring, because it proves that the combination of the two technologies is effective and can play their original advantages. Not all good technologies can be combined effectively. However, the lack of innovation also makes the article somewhat boring.

4.6. Conclusion and personal reflection

This article is a good combination of traditional technology and deep learning technology in the field of image restoration, and has been effectively verified.

If I were tasked to solve the research problem, I might be more focused on how to use the deep learning methods generated after this article to improve the performance of the denoiser.

This article taught me that in the low-level vision field, the combination of traditional image technology and deep learning technology is effective and can retain the advantages of both. If I are engaged in research in the corresponding field in the future, this kind of thinking may be an effective and feasible solution.

References

[1] Kai Zhang and Wangmeng Zuo and Shuhang Gu and Lei Zhang. *Learning Deep CNN Denoiser Prior for Image Restoration*. 2017, arXiv, cs.CV 1

[2] Ziyu Wan and Bo Zhang and Dongdong Chen and Pan Zhang and Dong Chen and Jing Liao and Fang Wen. *Old Photo Restoration via Deep Latent Space Translation* 2020, arXiv, cs.CV 1

[3] Zhouchen Lin, Minming Chen, Yi Ma. *The Augmented Lagrange Multiplier Method for Exact Recovery of Corrupted Low-Rank Matrices* 2010, arXiv, cs.CV 2