Meta-learning for solving inverse problem

Qingqing Zhao

February 2021

1 Motivation and Background

Considering the image formation model [1], where x is the ground truth signal, $A(\cdot)$ represent the image formation process, ϵ is noise and y is the observation, the problem of reconstructing unknown signal x from y is called inverse problem. Many image processing problems can be formulated as inverse problems including deblurring, inpainting, etc. Therefore, developing general algorithms for solving inverse problems is of great interest.

$$y = A(x) + \epsilon \tag{1}$$

One biggest challenge of solving the inverse problem comes from the fact that the image formation process, $A(\cdot)$, is in general non-invertible. This makes the inverse problem ill-posed and hence hard to find a unique solution without any prior information of the signal. Classical methods of solving inverse problems involving minimize both data-fidelity term and a regularization term. Our idea builds upon classical algorithms where we want to use meta-learning techniques, to learn a good initialization for the classical algorithm, so that it can converge to good solutions.

2 Related Work

2.1 Meta-learning

Meta-learning, also called learning to learn, is the process of improving a learning algorithm through many episodes of training[2]. In this project, we will mainly focus on one type of meta-learning algorithm[1], where is first introduced to learn a good initialization for a neural network, so that it can quickly adapt to different tasks with few gradient updates. The main idea in our problem would be to meta-learn an initialization for classical solver so that it can converge quickly to good solutions.

2.2 Implicit representation

Implicit representations of signals using the neural network have emerged as a powerful paradigm. Recent works have demonstrated that MLPs with sinusoidal activation functions are capable of representing complex natural signals with high granularity[5]. Here we want to use represent our initialization for classical solver using implicit representation. Note that there are also several works combining meta-learning with implicit representations.

3 Project Overview and Milestones

The goal of the project is to use meta-learning to learn a good initialization for classical solvers for the inverse problem. I will test proposed frameworks on the inpainting problem and the deblurring (deconvolution) problem. We will use CelebA[3] as the training dataset to generate inpainted/blurred images.

1. week 7: read about MAML[1] and implicit representation [5]; formulate the algorithm and the training scheme.
2. week 8: develop PyTorch pipeline for the proposed algorithm; implement inpainting/deblurring task.
3. week 9: train the network; perform ablation tests; train baseline[4] for comparison.
4. week10: evaluation of the proposed scheme on the inpainting task, using metrics like PSNR, SSIM, and LPIPS.

References

[1] Chelsea Finn, Pieter Abbeel, and Sergey Levine. *Model-Agnostic Meta-Learning for Fast Adaptation of Deep Networks.* 2017.

[2] Timothy Hospedales, Antreas Antoniou, Paul Micaelli, and Amos Storkey. *Meta-Learning in Neural Networks: A Survey.* 2020.

[3] Ziwei Liu, Ping Luo, Xiaogang Wang, and Xiaoou Tang. Deep learning face attributes in the wild. In *Proceedings of International Conference on Computer Vision (ICCV)*, December 2015.

[4] Olaf Ronneberger, Philipp Fischer, and Thomas Brox. U-net: Convolutional networks for biomedical image segmentation, 2015.

[5] Vincent Sitzmann, Julien N. P. Martel, Alexander W. Bergman, David B. Lindell, and Gordon Wetzstein. *Implicit Neural Representations with Periodic Activation Functions.* 2020.