Internship and PhD proposal
Regularization with generative neural networks for satellite imaging

ISAE-SUPAERO & CNES
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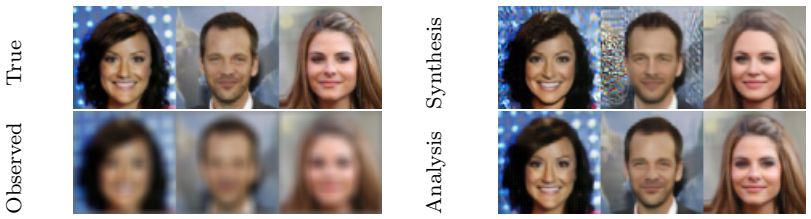

Figure 1: Illustration: deblurring results from [4].

1 Presentation

Deep neural networks achieved a major breakthrough in computer vision in the past decade, enabling a dramatic increase in performance for supervised tasks such as image classification or segmentation. In the last few years, neural networks have also been successfully applied to image processing or reconstruction tasks such as denoising, deblurring, compression, pan-sharpening or super-resolution [3, 2]. The standard approach directly solves the image reconstruction task, by end-to-end training a deep convolutional network on a large amount of data. If a physical model is known (for instance, the point-spread function for the deblurring task), it can be used to simulate the pairs of clean and degraded images. In spite of their impressive performance, such end-to-end approaches can hardly be used in satellite imaging, for at least two reasons. First, such deep architectures are hardly interpretable and exhibit instabilitites, which limit the confidence in the reconstructed image. Second, their training require both a large amount of GPU time and the tuning of numerous hyper-parameters. This is particularly problematic in the context of satellite imaging, since the specificities of the physical model (noise level, PSF, spectral responses) require to retrain the network for each instrument.

More recent works investigated an alternative way, which consists in using well-known model-based inversion, the neural networks being used only for regularization. The seminal work in the literature [1] capitalized on deep generative models, such as variational autoencoders (VAEs) or generative adversarial networks (GANs). It consists in a synthesis regularization, where the solution is searched in the latent space of the generative model. In a recent work [4], we showed that a direct inversion in the image space, termed analysis regularization, can lead to better results, especially in the case where the sought image does not exactly lie in the range of the generative model. This will be the case in satellite imaging, where the size, diversity and complex nature of images prevent to learn a generative model that perfectly captures the statistics of the images in the dataset.

2 Objectives of the internship

The objectives of the internship are to consolidate and extend the results of [4]. It should lead to a PhD thesis (for which a funding grant has been planned), whose aim is to generalize this approach to make it cope

with the diversity of satellite images. The proposed methods will be adapted and challenged on several real applications in satellite imaging, such as image denoising, compression artefact removal, image deblurring or super-resolution.

The supervision team is composed of academic researchers in image processing and machine learning, as well as engineers in satellite imaging at CNES. The internship will be hosted by ISAE-SUPAERO, and the PhD student will share its time between ISAE and CNES. The supervision team is composed of:

- Thomas Oberlin, Associate Professor at ISAE-SUPAERO,
- Marie Chabert, Professor at Toulouse INP & IRIT,
- Florence Genin and Christophe Latry, CNES (DSO/SI/QI)

3 Candidate profile

We are seeking for an outstanding candidate holding a M. S. or an Engineer's degree in image processing, machine learning or a related field in computer science or applied mathematics. The candidate should demonstrate extensive knowledge in image processing, deep neural networks and Bayesian modeling, as well as a strong interest for satellite imaging and Earth observation. Fluency in English and good communication and writing skills are also required.

Please send your application by email to thomas.oberlin@isae-supaero.fr. It should contain:

- a detailed curriculum,
- student transcripts from the last two years,
- and a motivation letter (optional).

The intern will be granted the usual French stipend of ~ 600 euros/month. If the candidate is successful, this internship will be pursued by a PhD, whose salary is ~ 2045 euros/month.

References

[1] Bora, A., Jalal, A., Price, E., & Dimakis, A. G. *Compressed sensing using generative models.* Proc. ICML, 2017.

[2] Cresson, R. *Deep Learning for Remote Sensing Images with Open Source Software.* CRC Press, 2020.

[3] Kim, J., Lee, J. K., & Lee, K. M. *Accurate image super-resolution using very deep convolutional networks.* In Proc. CVPR, 2016.

[4] Oberlin, T. & Verm, M. *Regularization via deep generative models: an analysis point of view.* Proc. ICIP, 2021.