Fast and high-quality computational imaging with simple lenses

Advisors: Paul Escande (CR CNRS) & Emmanuel Soubies (CR CNRS)

Practical informations:

Host: Institut de Mathématiques de Toulouse

Location: Campus of the Université Paul Sabatier, Toulouse.

Duration: 4 to 6 months starting from March/April 2025 – potential Ph.D. in October 2025.

Candidate profile: Strong background in mathematics required with an interest in inverse problems, machine learning and optimization. Proficiency in Python/Torch appreciated.

Salary: The intern will be granted the usual stipend of 600 euros/month.

Contact: paul.escande@math.univ-toulouse.fr or emmanuel.soubies@irit.fr

Keywords: Deblurring, inverse problems, computational imaging, deep learning

Context: Contemporary lenses are highly sophisticated systems consisting of up to two dozens of optical elements. This complexity is essential to compensate for the geometric and chromatic aberrations of a single lens that are responsible for blurry images. Some works [4] have proposed to remove these artifacts using computational imaging, that is coupling the lens with a numerical algorithm. This allows the correction of images captured with simple optics that are lighter and significantly less expensive. However, these algorithms are computationally intensive and they require a precise estimation of the blur (calibration), which probably explains why these ideas have not taken off.

On the other hand, we have build over the years an expertise in the design of :

- fast and accurate deblurring algorithms [3] speeding up computation times by a factor 1000
- precise estimation procedures of the blur operator [2]

While being fast, these approaches do not compete with state-of-the-art restoration methods based on deep learning [1].

Topic: In this context, the internship aims to combine our expertise to deep learning techniques in order to derive fast and high-quality reconstruction algorithms. Another goal of this internship is to showcase their efficiency by implementing them on low-consumption embedded systems. We have at our disposal a customized simple lens that has been calibrated and a Nvidia Jetson Xavier containing a high-performance GPU with a 30W consumption (instead of 300W for standard deep-learning oriented GPU).

Figure 1: Left: the Nvidia Jetson Xavier. Center: the custom lens. Right: the field of point spread functions describing the blur induced by the lens at different locations.

References:

[1] Adler and Öktem. "Learned primal-dual reconstruction". In: *IEEE trans. on medical imaging* (2018).

[2] Bigot, Escande, and Weiss. "Estimation of linear operators from scattered impulse responses". In: *Applied and Comp. Harmonic Analysis* (2019).

[3] Escande and Weiss. "Fast wavelet decomposition of linear operators through product-convolution expansions". In: *IMA J. of Numerical Analysis* (2022).

[4] Heide et al. "High-quality computational imaging through simple lenses". In: *ACM Trans. on Graphics* (2013).