M2R internship proposal in machine learning / signal and image processing to be followed by a Ph.D project (2022-2025)

Learning physical features from polarimetric images with constrained matrix factorizations

Context Polarization information plays a major role in imaging. It allows to capture important characteristics of the observed medium, such as shape, roughness, orientation, physicochemical properties, etc. [1], [2]. These different features, often inaccessible to conventional intensity measurements, are key descriptors in many applications, including bioimaging characterization of cancerous tissues[3].

Summary Despite the numerous applications of polarization imaging, exploiting its full potential requires the development of new methodological tools that take into account the different physical constraints specific to the measurement and interpretation of polarization. This M2R internship will focus on developing *efficient algorithms to learn meaningful low-rank features from datasets of polarized images.* As a first task, the candidate will study dimension reduction techniques for Stokes parameter datasets – a set of four energetic parameters widely used to describe polarization properties in passive imaging. Given the large amount of Stokes data which can be collected in a growing range of applications thanks to the rapid emergence of polarization cameras, dimension reduction techniques are essential to ensure that physically relevant features can be rigorously inferred from data. This is a key step before further processing (clustering, classification, regression, etc.) To this aim the candidate will take advantage of recent low-rank matrix factorization tools introduced in [4], which exploit geometric / algebraic representations of Stokes parameter data using quaternions. He/she will propose novel algorithms to efficiently solve this constrained factorization problem. The proposed algorithms will be extensively benchmarked on both synthetic and experimental datasets from spectropolarimetry and polarization microscopy – both important applications modalities available at CRAN.

This internship is to be followed by a Ph.D research project, starting October, 2022. (more details)

Candidate profile He/she should be enrolled in a M2R or engineer diploma in one or more of the following fields: signal and image processing, machine learning, applied mathematics. The candidate should have good writing and oral communication skills.

Supervision and environment This M2R internship will be jointly supervised by Julien Flamant (CNRS research scientist) and Sebastian Miron (Associate Professor HdR at Université de Lorraine). The candidate will be located at (CRAN UMR 7039, `http://www.cran.univ-lorraine.fr/`) in Vandoeuvre-lès-Nancy, 54500 France, where he will join Simul research group (`https://cran-simul.github.io`).

References

[1] J. S. Tyo, D. L. Goldstein, D. B. Chenault, *et al.*, "Review of passive imaging polarimetry for remote sensing applications," *Applied optics*, vol. 45, no. 22, pp. 5453–5469, 2006.

[2] N. Ghosh and A. I. Vitkin, "Tissue polarimetry: Concepts, challenges, applications, and outlook," *Journal of biomedical optics*, vol. 16, no. 11, p. 110 801, 2011.

[3] A. Pierangelo, A. Benali, M.-R. Antonelli, *et al.*, "Ex-vivo characterization of human colon cancer by mueller polarimetric imaging," *Optics express*, vol. 19, no. 2, pp. 1582–1593, 2011.

[4] J. Flamant, S. Miron, and D. Brie, "Quaternion non-negative matrix factorization: Definition, uniqueness, and algorithm," *IEEE Transactions on Signal Processing*, vol. 68, pp. 1870–1883, 2020.