Bayesian inference and optimal transport for change detection between heterogeneous images

– M.Sc. proposal in machine learning and signal/image processing –

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Abstract

This internship will consist in developing methods for detecting changes between heterogeneous images in a probabilistic framework, on the one hand to take advantage of the optimal transport framework, and on the other hand of Bayesian inference. By defining the change detection problem as a fusion problem, and building on the work done in optimal transport, this internship aims to propose a new method for learning changes between two multispectral and hyperspectral images. The main expectations of this project are the development of a methodology and an open access algorithm for the detection of changes between images of different resolutions. These tools will be applied to real images, in particular for Earth observation and astrophysics, as follow-up to the works of [1, 2, 3] and [4, 5], respectively.

Keywords

Machine learning, Signal and image processing, optimal transport, Bayesian inference.

Detailed description

Being acquired by the same sensor, identifying these changes is easy and straightforward. However, when considering multi-band images acquired through sensors of different modalities, change detection becomes considerably more complicated ; examples include emergency situations and one-off missions. The usual approach is to independently apply a transformation to each image so that they have the same resolution, both spectral and spatial. However, this pre-processing step discards the coupled information of the images. Recently, V. Ferraris, N. Dobigeon and M. Chabert proposed to view the change detection problem as a robust image fusion problem by constructing two latent images of the same resolution as degraded versions of the observed image [3]. The latent images are then merged by imposing spatial sparsity, highlighting the changes between two observed images.

Thereafter, the aim of this internship will be to add a Bayesian framework for, initially, the fusion of hyperspectral and multispectral images : by introducing a prior distribution on the parameters and hyperparameters, the fusion problem can be formulated in a Bayesian setting, which allows to easily model the noise and the target image. The high spectral and spatial resolution image is then recovered from its posterior, and this optimal transport induced method for modelling the transport from the prior to the posterior will be considered, and implemented. In a second stage, the detection of changes between heterogeneous images will be considered as an application of the fusion problem. A large part of this internship will be dedicated to the proposal of efficient algorithms and to the development of a toolbox to solve these image processing problems ; with an emphasis on techniques coupling information from both images, and on applications to real data.

Scientific environment

The M.Sc. student will therefore benefit from a favorable context and will be able to rely on the most recent results and advances in signal & image processing and machine learning. He/she will be mainly co-advised by the following researchers within the SC

group at IRIT laboratory (UMR CNRS 5505, Toulouse) :
- Elsa Cazelles, CNRS Researcher
- Nicolas Dobigeon, Professor at Toulouse INP and AI Research Chair at the Artificial and Natural Intelligence Toulouse Institute (ANITI)
- Marie Chabert, Professor at Toulouse INP

Period and continuation as a Ph.D. thesis

This internship shall take place in 2022. The precise starting and ending dates can be adjusted according to the availability of the selected candidate.

A **Ph.D. position** will be considered as a possible continuation of this M.Sc. training period.

Profile & requirements

Master or Engineering school students with major in applied mathematics, computer science or electrical engineering.

The knowledge needed for this work includes a strong background in **signal & image processing**, **applied mathematics** (probability & statistics, optimization, etc.) and/or machine learning. Good scientific programming skills (e.g., Python or Matlab) and good communication skills in English, both written and oral are also expected.

Contact & application procedure

Applicants are also invited to send (as pdf files)
- a detailed curriculum,
- official transcripts from each institution you have attended (in French or English).

to the co-advisors
- Elsa Cazelles, elsa.cazelles@irit.fr
- Nicolas Dobigeon, nicolas.dobigeon@irit.fr
- Marie Chabert, marie.chabert@irit.fr

You will be contacted if your profile meets the expectations. Review of applications will be closed when the position is filled.

References

[1] V. Ferraris, N. Dobigeon, Q. Wei and M. Chabert, "Robust fusion of multi-band images with different spatial and spectral resolutions for change detection," *IEEE Trans. Computational Imaging*, vol. 3, no. 2, pp. 175-186, April 2017.

[2] V. Ferraris, N. Dobigeon, Q. Wei and M. Chabert, "Detecting changes between optical images of different spatial and spectral resolutions : a fusion-based approach," *IEEE Trans. Geoscience and Remote Sensing*, vol. 56, no. 3, pp. 1566-1578, March 2018.

[3] V. Ferraris, N. Dobigeon and M. Chabert, "Robust fusion algorithms foe unsupervised change detection between multi-band optical images – A comprehensive case study", *Information Fusion*, vol.64, p.293–317, 2020.

[4] C. Guilloteau, T. Oberlin, O. Berné, É. Habart and N. Dobigeon, "Simulated JWST datasets for multispectral and hyperspectral image fusion," *The Astronomical Journal*, vol. 160, no. 1, June 2020.

[5] C. Guilloteau, Th. Oberlin, O. Berné and N. Dobigeon, "Hyperspectral and multispectral image fusion under spectrally varying spatial blurs - Application to high dimensional infrared astronomical imaging," *IEEE Trans. Computational Imaging*, vol. 6, pp. 1362-1374, Sept. 2020.