Phd Thesis Subject

Title: Leaf Hyperspectral Unmixing via Non-negative Matrix Factorization. Application to remote supervision of agricultural crops using Hyperspectral Imagery.

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Team: SPeciFI
Scientific topic: Signal Processing

1. Introduction

Precision farming is booming during last years thanks to new digital acquisition technologies and the advent of smart IoT sensors. In order to evaluate the stress state of a crop, its exposure to fungal diseases or its water needs, the use of mobile hyperspectral imaging in the vicinity of plots to be diagnosed is a very relevant choice [12,13].

The use of a drone or aircraft [11] equipped with a hyperspectral camera produces lots of images over hundreds of channels describing a scene in visible InfraRed or Middle InfraRed light. Navigating an agricultural area with such a device makes it possible to provide hyperspectral reflectance images in the form of a "data cube", the deployment of which provides a matrix (locations x wavelengths).

Typically, each observed pixel is treated as a mixture of different vegetation types or different states of the same vegetation and soil. This matrix is thus assimilated to a linear mixture between the different pure spectra represented by the soils, the healthy leaves and the sick or stressed leaves of the studied culture. Recovering the part of each pure spectrum amounts to perform an unmixing step into several pure spectra.

Non-negative matrix factorization (NMF) methods approximate data to a linear combination of non-negative latent factors. One of the factors represents the different signatures present in the scene (pure spectra), while the other factor represents the description of the contribution of each pure spectrum for each pixel. These methods are widely used in both the Signal Processing and Machine Learning communities. They present the advantage to yield decompositions whose physical interpretation is consistent with the non-negative features of the decompositions.

In hyperspectral imaging, an additional specific constraint of factors expresses the sum-to-one of the relative abundances associated with the different pure spectra to be recovered [9, 10]. This sum-to-one constraint has been also used in our previous work applied to the separation of aerosol particle sources from sample concentration measurements. This constraint can be integrated again into the new informed NMF method able to perform this spectral unmixing.

The NMF decomposition is also corrupted by the spatial and time variability of the pure spectra and the evolving light conditions. Over the last decade, we have developed robust methods [1-5] able to take into account the possible outliers in the data and we intend again to exploit these techniques so that the estimates are robust to these variations [7,10]. Beyond this problem modeling, it is also necessary to adapt the algorithms for a fast processing of such a large amount of data [6], to allow analysis in a slight deferred time.

The major interest for the agricultural community and surrounding startups is to be able to estimate and locate as soon as possible the rate of sick vegetation in a field, in order to select areas to apply appropriate fungal treatments and prevent the spread of diseases to healthy areas.

2. Phd thesis planning

The selected candidate will have to conduct experiments in order to drive the UAV in an appropriate way and to derive data measurements from the Hyperspectralcamera able to be processed for further unmixing tasks.

While driving an extensive bibliography work, the candidate will have to develop strategies able to inform the NMF in order to extract pure spectra.

During the project, the PhD candidate will have close contact with specialized companies involved in the project.

Keywords: Informed Nonnegative Matrix Factorization or Tensor Factorization; Machine Learning; precision agriculture; Hyper-spectral Imaging.

3. References:

[1] **R. Chreiky** , Informed Non-Negative Matrix Factorization for Source Apportionment, Phd thesis defended on December 20th 2017.
[2] **A. Limem**, G. Delmaire, M. Puigt, G. Roussel, D. Courcot. Non-negative matrix factorization under equality constraints - a study of industrial source identification. Elsevier Applied Numerical Mathematics, Volume 85, November 2014, Pages 1–15.
[3] **A. Limem**, M. Puigt, G. Delmaire, G. Roussel, D. Courcot. Bound constrained weighted NMF for industrial source apportionment. Proceedings of the 24th IEEE International Workshop on Machine Learning for Signal Processing (MLSP 2014), Reims, France, September 21-24, 2014.
[4] **R. Chreiky**, G. Delmaire, M. Puigt, G. Roussel, A. Abche, Informed split gradient non-negative matrix factorization using Huber cost function for source apportionment, Proceedings of the 16th IEEE International Symposium on Signal Processing and Information Technology (ISSPIT 2016), Limassol, Cyprus, December 12-14, 2016.
[5] **R. Chreiky**, G. Delmaire, C. Dorffer, M. Puigt, G. Roussel, A. Abche, Robust informed split gradient NMF using Alpha Beta-divergence for source apportionment, Proceedings of the 26th IEEE International Workshop on Machine Learning for Signal Processing (MLSP 2016), Vietri Sul Mare, Salerno, Italy, September 13-16, 2016.
[6] **C. Dorffer**, M. Puigt, G. Delmaire, G. Roussel, *Fast nonnegative matrix factorization and completion using Nesterov iterations*, Proceedings of the 13th International Conference on Latent Variable Analysis and Signal Separation (LVA/ICA 2017), Springer International Publishing AG, vol. LNCS 10179, pp. 26-35, Grenoble, France, February 21-24, 2017.
[7] Charlotte Revel, Yannick Deville, Véronique Achard, Xavier Briottet. A method based on nonnegative matrix factorization dealing with intra-class variability for unsupervised hyperspectral unmixing. WHISPERS 2015: 1-4.
[8] M. Puigt, G. Delmaire, G. Roussel, Environmental signal processing : new trends and applications, Proceedings of the 25th European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning (ESANN 2017), Bruges, Belgium, April 26-28, 2017.
Article d'introduction à la session spéciale organisée par G. Delmaire, M. Puigt et G. Roussel à cette conférence.

[9] José M. Bioucas Dias, Blind Hyperspectral Unmixing. 13th International Conference on Latent Variable Analysis and Signal Separation, February 2017, Grenoble, France.
[10] P. A. Thouvenin, Modeling spatial and temporal variabilities in hyperspectral image unmixing. Thèse de doctorat, Université de Toulouse, 17 octobre 2017.
[11] J. Franke, T. Mewes, G. Menz, Airborne hyperspectral imaging for the detection of powdery mildew in wheat. Imaging Spectrometry XIII, Proc Spie, Vol. 7086, doi: 10.1117/12.795040, 2008.
[12] Youssef Es-saady, Ismail El Massi, Mostafa El Yassa, Driss Mammass, Abdeslam Benazoun, Détection précoce des maladies des plantes par la technique d'imagerie hyperspectrale, 5 ème édition Colloque Groupe Hyperspectral SFPT-GH 9 - 11 MAI 2017, Ifremer – Centre de Bretagne.
[13] Chuanqi Xie, Yongni Shao, Xiaoli Li & Yong He, Detection of early blight and late blight diseases on tomato leaves using hyperspectral imaging . Nature.com , Scientific Reports | 5:16564 | DOI: 10.1038/srep16564.

4. What we offer:

A team composed of one full and two associate professors, and several students (currently, 1 Ph.D. student and 1 M.Sc student) involved in matrix factorization problems (with both various objectives and applications) ;
An interdisciplinary work in collaboration with Pr. Eric Ramat (LISIC) and a specialized company in
Computing facilities (a PC, access to ULCO computing servers), and University cloud services.

5. Practical information:

The salary and appointment terms are consistent with the current rules for PhD degree students. The gross research allowance is **1685 Euros** monthly. The period of employment is 3 years.

The Ph.D. thesis will take place in the LISIC lab, located in Calais on the Opal Coast, nearby Great Britain and Belgium. The Opal Coast is well-known for outdoor activities (trekking, biking, wind-surfing, kite-surfing, horsing, ...).
Moreover, the city of Calais enjoys a rich cultural activity (public and art & experimental cinemas, concert venues, several museums, and regular cultural activities).

6. Approval and Enrolment:

The scholarships for the PhD degree are subject to academic approval, and the candidates will be enrolled in one of the general degree programmes of ED SPI . For information about the requirements for enrolment and the general planning of the scholarship studies, please refer to their website.

7. Requested skills:

We are looking for a curious student with excellent programming skills (e.g., in Matlab, Python, or C/C++). The candidate must have some strong background in computer science (e.g., signal processing, machine learning), applied maths, or any field related with the proposed subject.
Moreover, the candidate should specify at least its level in both French and English according to the COMMON EUROPEAN FRAMEWORK OF REFERENCE FOR LANGUAGES.

Besides, a basic knowledge of LateX programming environment would be enjoyed.

9. Application

Application should be done by email to gilles.delmaire@univ-littoral.fr and gilles.roussel@univ-littoral.fr no later than 20 Mars 2019 with requested documents. The email should include different files with

-A resume (in French)
-A letter motivating the application (cover letter in French)
-Curriculum vitae in French and English
-Grade transcripts and BSc/MSc diploma (an official translation into English and French)
-Recommendation letters (or at least a list of references) will be appreciated.
- Potentially, a scientific publication will be enjoyed.

Further information, contact
gilles.delmaire@univ-littoral.fr and gilles.roussel@univ-littoral.fr