NON-LINEAR UNMIXING AS AN INNOVATIVE TOOL TO DETECT VINE DISEASES IN UAVs, AIRBORNED AND SATELLITE IMAGES: PRELIMINARY RESULTS

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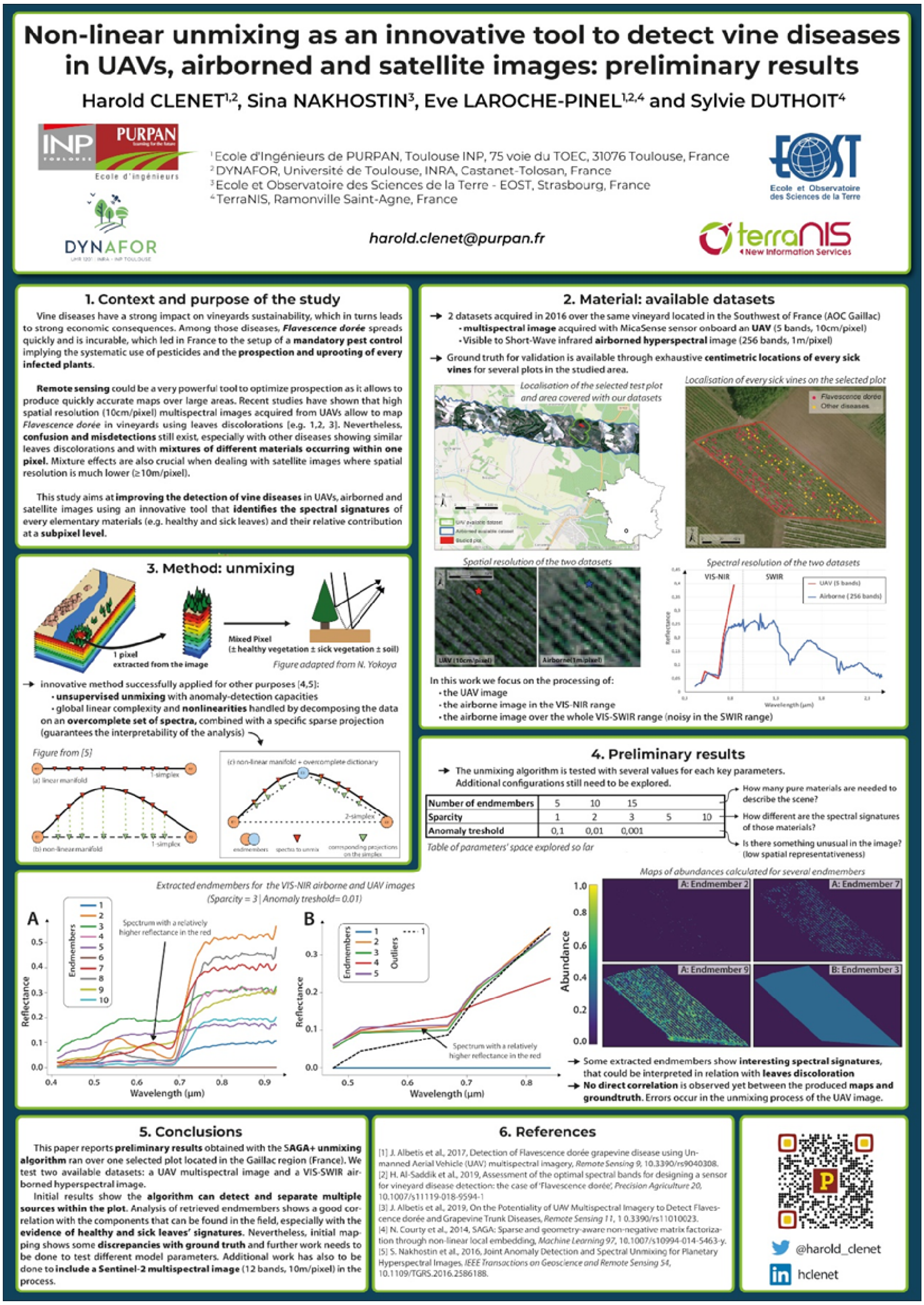
Abstract:
Context and purpose of the study - Vine diseases have a strong impact on vineyards sustainability, which in turns leads to strong economic consequences. Among those diseases, *Flavescence dorée* spreads quickly and is incurable, which led in France to the setup of a mandatory pest control implying the systematic use of pesticides and the prospection and uprooting of every infected plants. Remote sensing could be a very powerful tool to optimize prospection as it allows to produce quickly accurate maps over large areas. Recent studies have shown that high spatial resolution (10cm/pixel) multispectral images acquired from UAVs allow to map *Flavescence dorée* in vineyards using leaves discolorations [e.g. Albetis et al., Remote Sensing, 2017]. Nevertheless, confusion and misdetections still exist, especially with other diseases showing similar leaves discolorations and with mixtures of different materials occurring within one pixel. Mixture effects are also crucial when dealing with satellite images where spatial resolution is much lower (≥10m/pixel). This study aims at improving the detection of vine diseases in UAVs, airborned and satellite images using an innovative tool that identifies the spectral signatures of every elementary materials (e.g. healthy and sick leaves) and their relative contribution at a subpixel level.

Material and methods - We use three distinct datasets acquired in 2016 over the same vineyard located in the Southwest of France (AOC Gaillac): a multispectral image acquired with MicaSense sensor onboard an UAV (5 bands, 10cm/pixel), a Sentinel-2 multispectral image (12 bands, 10m/pixel) and an airborned hyperspectral image (256 bands, 1m/pixel). Ground truth for validation is available through exhaustive centimetric locations of every sick vines for several plots in the studied area. On the methodological perspective, we use an innovative method that performs an unsupervised unmixing jointly with anomaly-detection capacities and has a global linear complexity [Nakhostin et al., TGRS, 2016]. Nonlinearities are handled by decomposing the data on an overcomplete set of spectra, combined with a specific sparse projection, which guarantees the interpretability of the analysis.

Results - This paper reports preliminary results obtained with the unmixing algorithm ran over one selected plot available in the dataset. Initial results show the algorithm can detect and separate multiple sources within the plot. Analysis of retrieved endmembers shows a good correlation with the components that can be found in the field, especially with the evidence of healthy and sick leaves' signatures. Nevertheless, initial mapping still shows some discrepancies with ground truth and further work needs to be done to fine tune the model parameters.

Keywords: Vine diseases, Remote sensing, image processing, non-linear unmixing, satellite imagery, UAVs.

1. Introduction.


Non-linear unmixing as an innovative tool to detect vine diseases in UAVs, airborned and satellite images: preliminary results
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1. Context and purpose of the study
Vine diseases have a strong impact on vineyards sustainability, which in turns leads to strong economic consequences. Among those diseases, Flavescence dorée spreads quickly and is incurable, which led in France to the setup of a mandatory pest control implying the systematic use of pesticides and the prospection and uprooting of every infected plants.
Remote sensing could be a very powerful tool to optimize prospection as it allows to produce quickly accurate maps over large areas. Recent studies have shown that high spatial resolution (10cm/pixel) multispectral images acquired from UAVs allow to map Flavescence dorée in vineyards using leaves discolorations [e.g. 1,2, 3]. Nevertheless, confusion and misdetections still exist, especially with other diseases showing similar leaves discolorations and with mixtures of different materials occurring within one pixel. Mixture effects are also crucial when dealing with satellite images where spatial resolution is much lower (≥10m/pixel).
This study aims at improving the detection of vine diseases in UAVs, airborned and satellite images using an innovative tool that identifies the spectral signatures of every elementary materials (e.g. healthy and sick leaves) and their relative contribution at a subpixel level.
2. Material: available datasets
2 datasets acquired in 2016 over the same vineyard located in the Southwest of France (AOC Gaillac)
• multispectral image acquired with MicaSense sensor onboard an UAV (5 bands, 10cm/pixel)
• Visible to Short-Wave infrared airborned hyperspectral image (256 bands, 1m/pixel)
Ground truth for validation is available through exhaustive centimetric locations of every sick vines for several plots in the studied area.
Localisation of the selected test plot and area covered with our datasets
Localisation of every sick vines on the selected plot
Flavescence dorée
Other diseases
Spatial resolution of the two datasets
UAV (10cm/pixel)
Airborne(1m/pixel)
Spectral resolution of the two datasets
VIS-NIR
SWIR
UAV (5 bands)
Airborne (256 bands)
Reflectance
Wavelength (µm)
In this work we focus on the processing of:
• the UAV image
• the airborne image in the VIS-NIR range
• the airborne image over the whole VIS-SWIR range (noisy in the SWIR range)
3. Method: unmixing
1 pixel extracted from the image
Mixed Pixel (± healthy vegetation ± sick vegetation ± soil)
Figure adapted from N. Yokoya
innovative method successfully applied for other purposes [4,5]:
• unsupervised unmixing with anomaly-detection capacities
• global linear complexity and nonlinearities handled by decomposing the data on an overcomplete set of spectra, combined with a specific sparse projection (guarantees the interpretability of the analysis)
Figure from [5]
(a) linear manifold
1-simplex
(b) non-linear manifold
1-simplex
(c) non-linear manifold + overcomplete dictionary
2-simplex
endmembers
spectra to unmix
corresponding projections on the simplex
4. Preliminary results
The unmixing algorithm is tested with several values for each key parameters. Additional configurations still need to be explored.
Number of endmembers 5 10 15
Sparcity 1 2 3 5 10
Anomaly treshold 0,1 0,01 0,001
Table of parameters' space explored so far
How many pure materials are needed to describe the scene?
How different are the spectral signatures of those materials?
Is there something unusual in the image? (low spatial representativeness)
Extracted endmembers for the VIS-NIR airborne and UAV images
(Sparcity = 3 | Anomaly treshold= 0.01)
A
B
Endmembers
Outliers
Spectrum with a relatively higher reflectance in the red
Reflectance
Wavelength (µm)
Maps of abundances calculated for several endmembers
Abundance
A: Endmember 2
A: Endmember 7
A: Endmember 9
B: Endmember 3
Some extracted endmembers show interesting spectral signatures, that could be interpreted in relation with leaves discoloration
No direct correlation is observed yet between the produced maps and groundtruth. Errors occur in the unmixing process of the UAV image.
5. Conclusions
This paper reports preliminary results obtained with the SAGA+ unmixing algorithm ran over one selected plot located in the Gaillac region (France). We test two available datasets: a UAV multispectral image and a VIS-SWIR airborned hyperspectral image.
Initial results show the algorithm can detect and separate multiple sources within the plot. Analysis of retrieved endmembers shows a good correlation with the components that can be found in the field, especially with the evidence of healthy and sick leaves' signatures. Nevertheless, initial mapping shows some discrepancies with ground truth and further work needs to be done to test different model parameters. Additional work has also to be done to include a Sentinel-2 multispectral image (12 bands, 10m/pixel) in the process.
6. References
[1] J. Albetis et al., 2017, Detection of Flavescence dorée grapevine disease using Unmanned Aerial Vehicle (UAV) multispectral imagery, Remote Sensing 9, 10.3390/rs9040308.
[2] H. Al-Saddik et al., 2019, Assessment of the optimal spectral bands for designing a sensor for vineyard disease detection: the case of 'Flavescence dorée', Precision Agriculture 20, 10.1007/s11119-018-9594-1
[3] J. Albetis et al., 2019, On the Potentiality of UAV Multispectral Imagery to Detect Flavescence dorée and Grapevine Trunk Diseases, Remote Sensing 11, 1 0.3390/rs11010023.
[4] N. Courty et al., 2014, SAGA: Sparse and geometry-aware non-negative matrix factorization through non-linear local embedding, Machine Learning 97, 10.1007/s10994-014-5463-y.
[5] S. Nakhostin et al., 2016, Joint Anomaly Detection and Spectral Unmixing for Planetary Hyperspectral Images, IEEE Transactions on Geoscience and Remote Sensing 54, 10.1109/TGRS.2016.2586188.
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