MINERAL IDENTIFICATION USING A NEW HYPERSPECTRAL LIBRARY AND SPARSE UNMIXING TECHNIQUES

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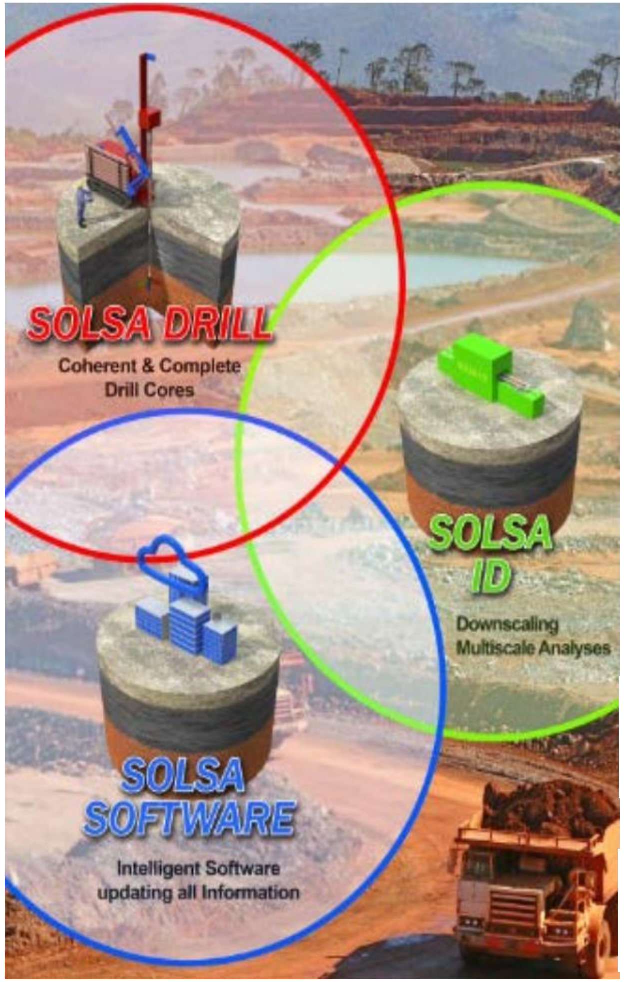
Introduction

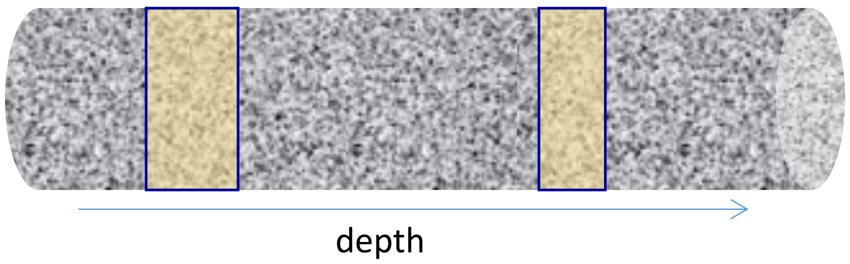
H2020 SOLSA (Sonic Online and Sample Analysis) project aims at constructing an analytical expert system for on-line-on-mine-real-time mineralogical and geochemical analyses on sonic drill cores.



SOLSA ID
Analyse & Identification in
field and industrial applications

SOLSA ID A, measurement	Profilometer, RGB camera, VNIR/SWIR cameras, XRF
SOLSA ID A, processing	Localisation of ROIs on drill cores
SOLSA ID B, measurement	XRD – XRF – Raman on ROIs
SOLSA ID B, processing	Data processing

Drill core (Drill core ID)



Contributions of this work:
- Build a new hyperspectral (SWIR) library
- Integrate the hyperspectral library into sparse unmixing techniques for mineral identification
- Evaluate the results

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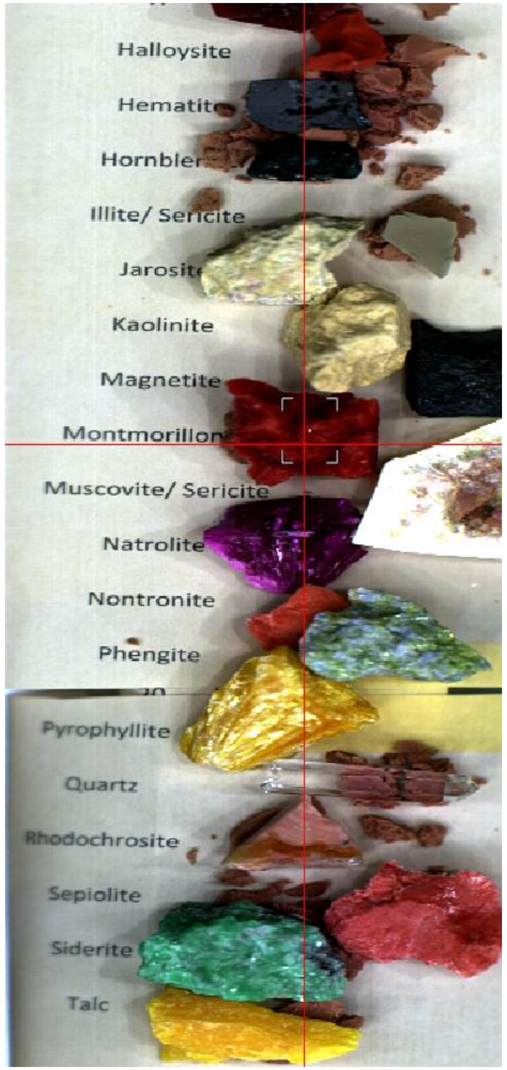
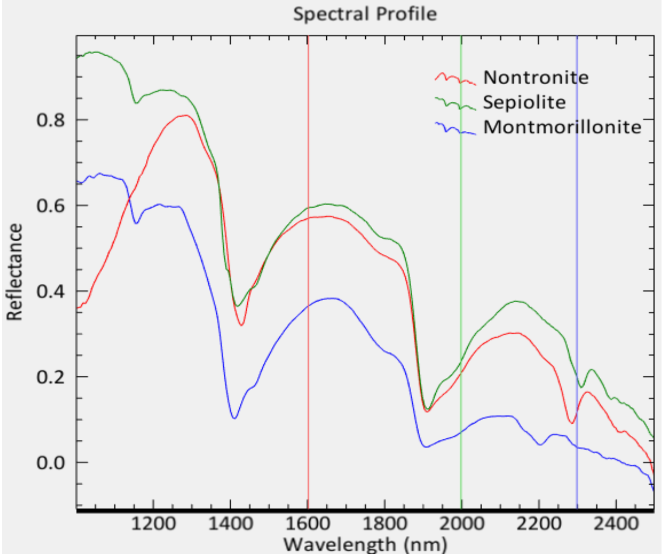
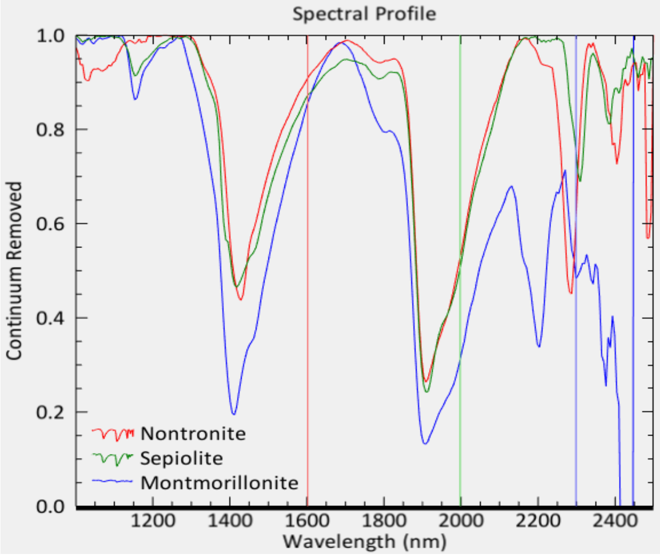
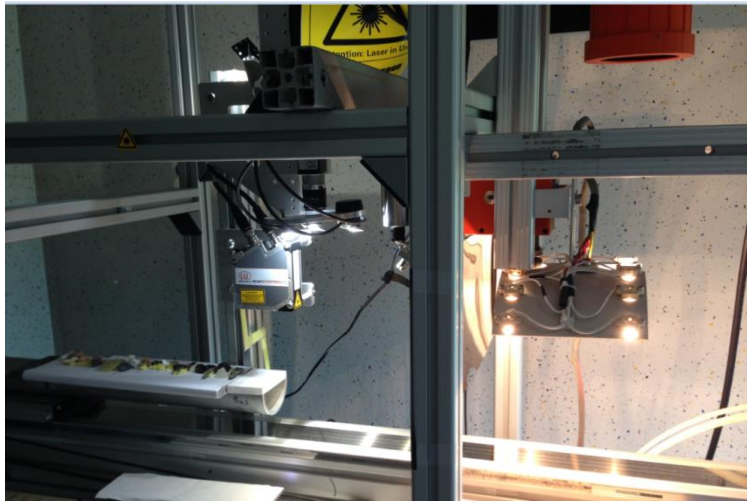
Methods – hyperspectral library (1/2)









- Rock and mineral samples provided by BRGM, ERAMET and the National Museum of Natural History, France
- Spectra extraction: ENVI 5.4 and G-MEX by taking into account the wavelength positions and the relative intensities of the absorption features.

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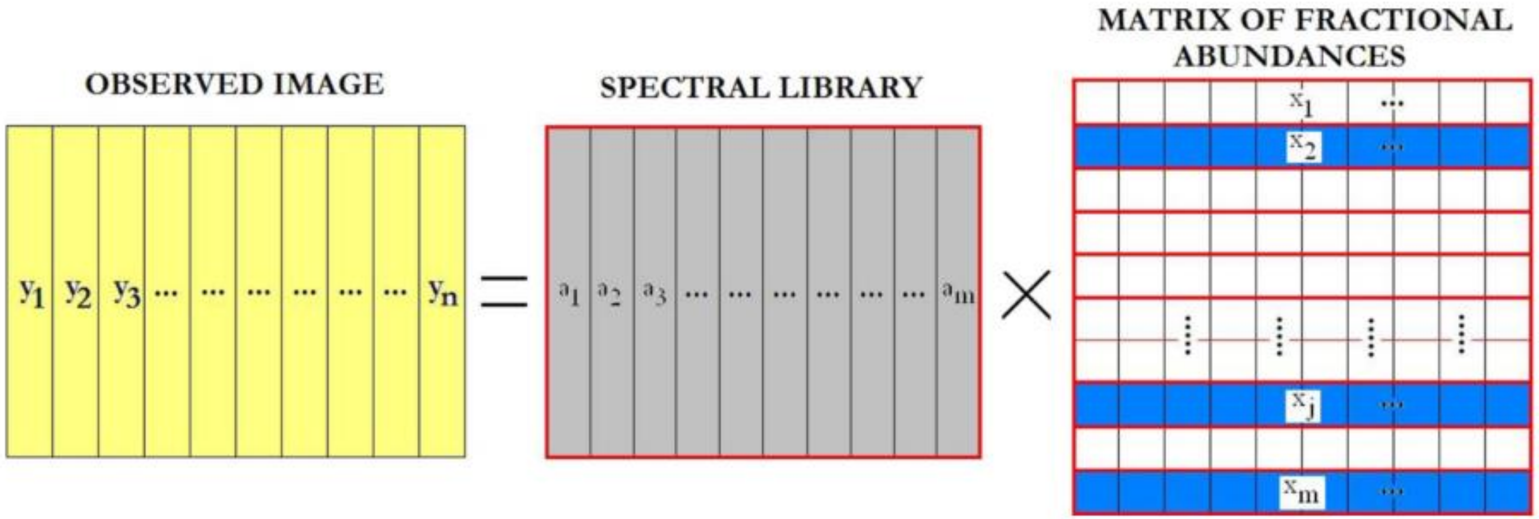
Methods – sparse unmixing (2/2)

$$Y = AX$$



Y L x n

A L x m

X m x n

$$\min_X \|AX - Y\|_F^{\,2} + \lambda \|X\|_{2,1}$$

subject to: X≥ 0, $\mathbf{1}^T$X = 1

Iordache *et al.*, IEEE Trans, 2014

- The observed image signatures can be expressed in the form of linear combinations of a number of pure spectral signatures known in advance (spectral library).
- Unmixing amounts to finding the optimal subset of signatures in a spectral library that can best model each mixed pixel in the scene.
- The sparse unmixing exploits the usual very low number of endmembers (maximum of 4, Berman *et al.*, CSIRO, 2017) present in real images, out of a spectral library.

More details

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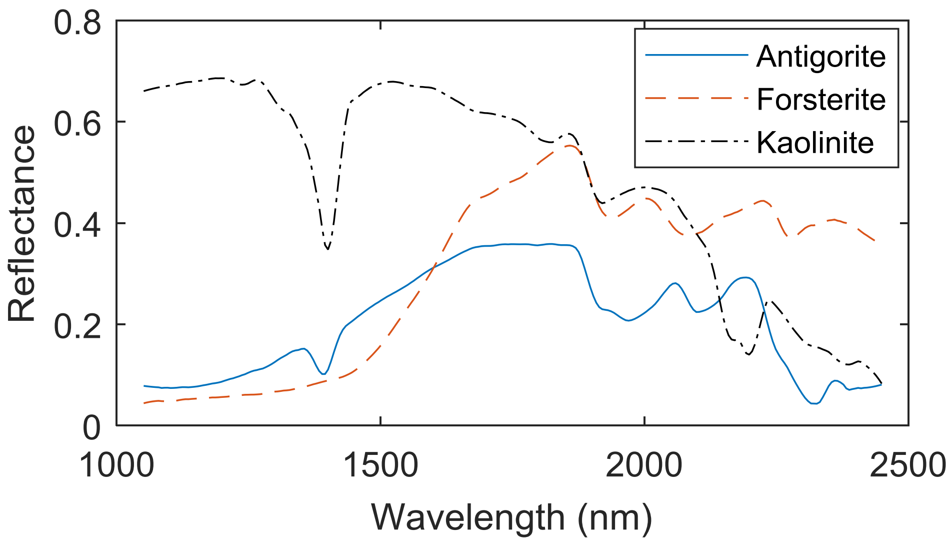
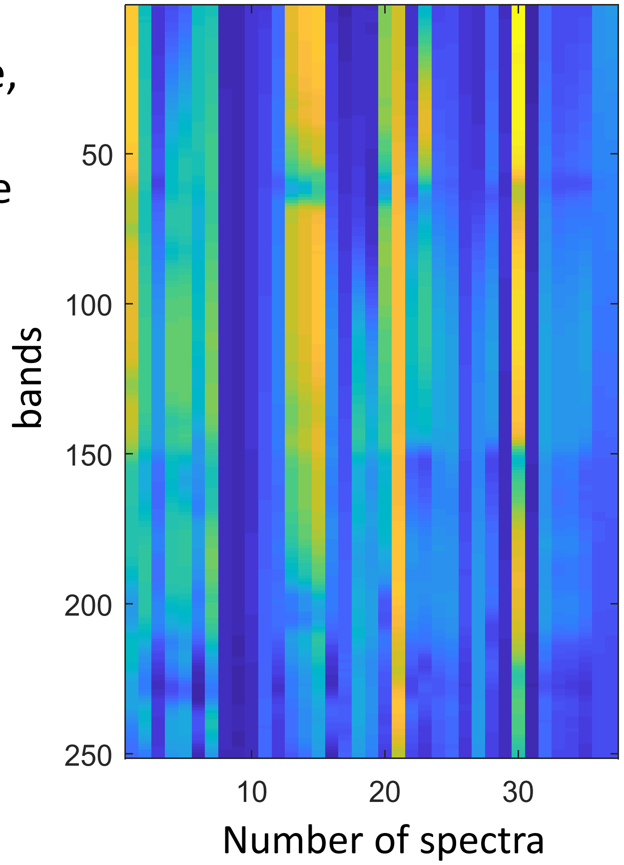
Results (1/2)

37 spectra representing 21 minerals have been collected:

ankerite, calcite, dolomite, magnesite
lizardite, nepouite, antigorite, chrysotite,
saponite, montmorillonite, nontronite, kaolinite, pimelite, talc, sepiolite,
alunite, asbolane, chromite, diaspore, enstatite, forsterite





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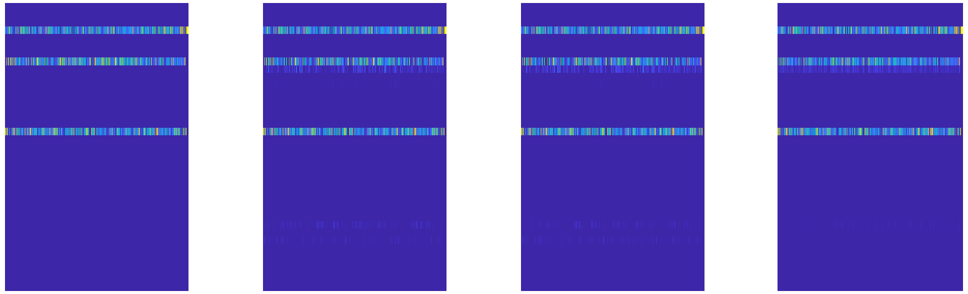
Results (2/2)

Simulated data

Original X | FCLS | SUnSAL | CLSUnSAL



Signal to reconstruction error (SRE) ratio

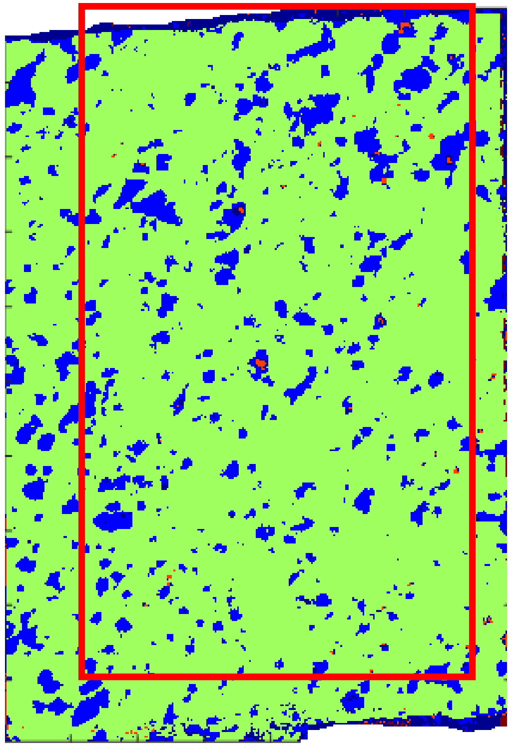
K	FCLS		SUnSAL		CLSUnSAL	
	SRE	Time	SRE	time	SRE	time
2	14.24	0.022	14.94	0.254	16.74	0.228
3	6.41	0.019	7.45	0.259	11.95	0.230
4	5.25	0.022	7.07	0.499	7.16	0.453

FCLS: Fully constrained least squares
SUnSAL: Sparse unmixing by variable splitting and augmented Lagrangian
CLSUnSAL: Collaborative sparse unmixing by variable splitting and augmented Lagrangian

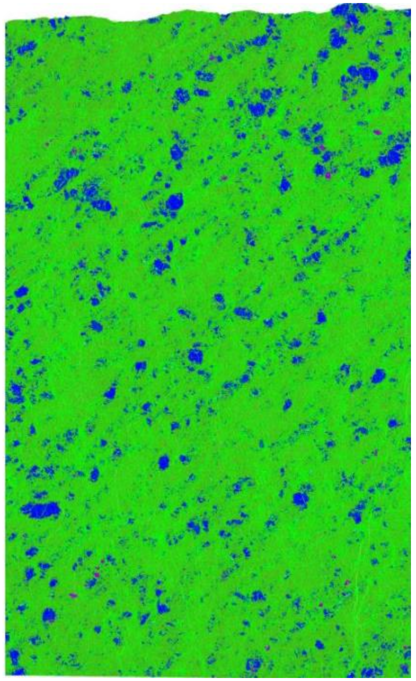
Data acquired from a serpentinized harzburgite sample

RGB image

Unmixing results



QEMSCAN results



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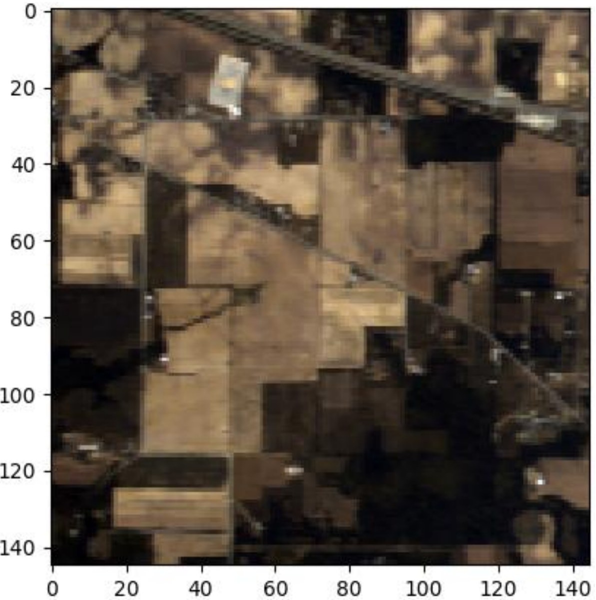
Conclusions

- A new hyperspectral library is under construction.
- Sparse unmixing, CLSUnSAL, method provides relatively accurate unmixing results.

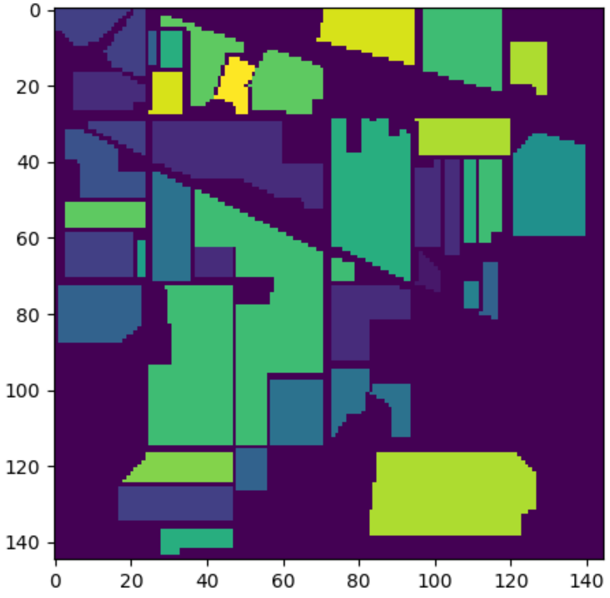
- Continue enlarging the hyperspectral library and evaluating the unmixing techiques
- For more efficient solutions, classification techniques have been developing : Random forests, SVMs and Deep learning (CNN)

More details

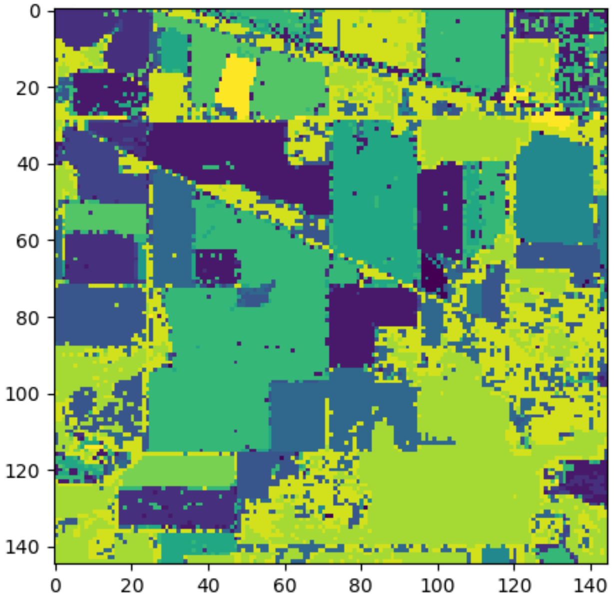
Indian pines dataset



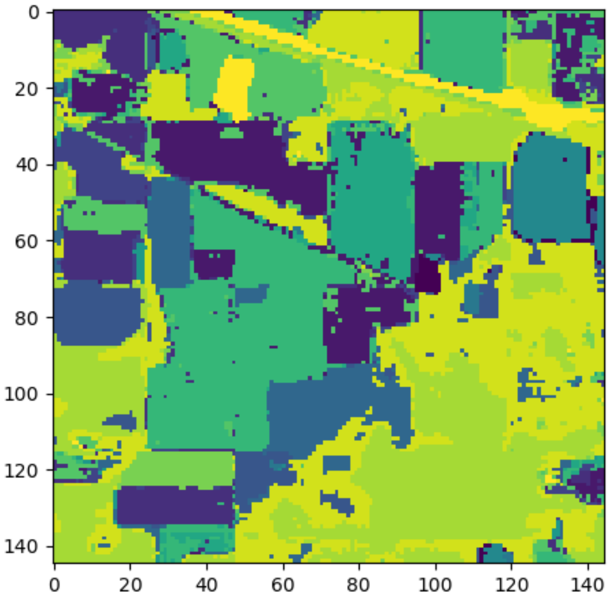
Ground truth



1D CNN,
Testing accuracy: 0.926



2D CNN,
Testing accuracy: 0.953



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Sparse unmixing:

X(m x n)

CLSUnSAL
(Collaborative sparse unmixing by variable splitting and augmented Lagrangian):

$$\min_{X} \|AX - Y\|_F^{\,2} + \lambda \|X\|_{2,1}$$

subject to: X ≥ 0, $\mathbf{1}^T$X = 1

SUnSAL
(Sparse unmixing by variable splitting and augmented Lagrangian):

$$\min_{X} \|AX - Y\|_F^{\,2} + \lambda \|X\|_{1,1}$$

subject to: X ≥ 0, $\mathbf{1}^T$ X = 1

FCLS
(Fully contrained least squares):

$$\min_{X} \|AX - Y\|_F^{\,2}$$

subject to: X ≥ 0, $\mathbf{1}^T$ X = 1

The optimization is based on the alternating direction method of multipliers (ADMM)

Iordache *et al.*, IEEE Trans, 2014

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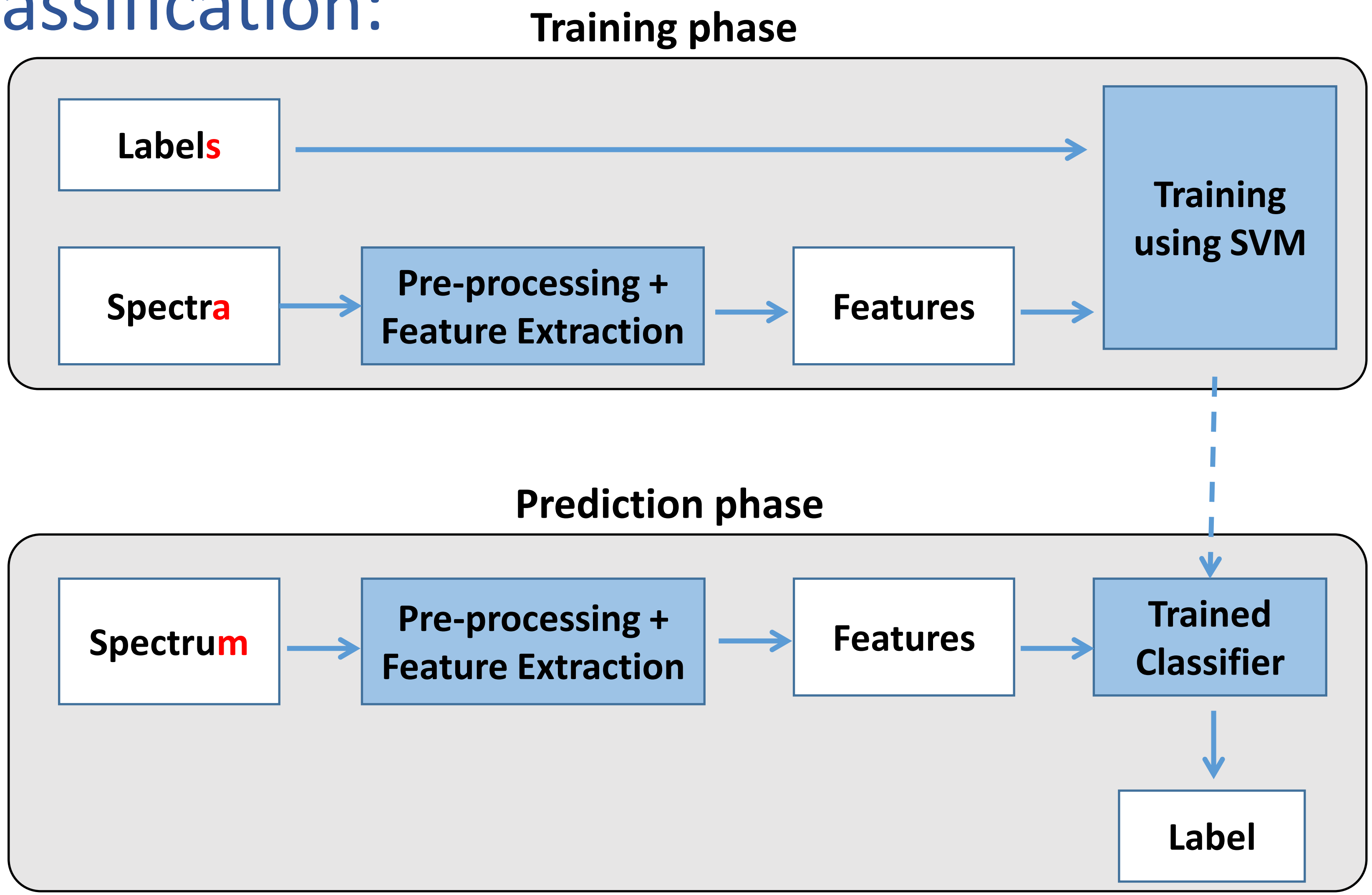
Classification:



SOLSA

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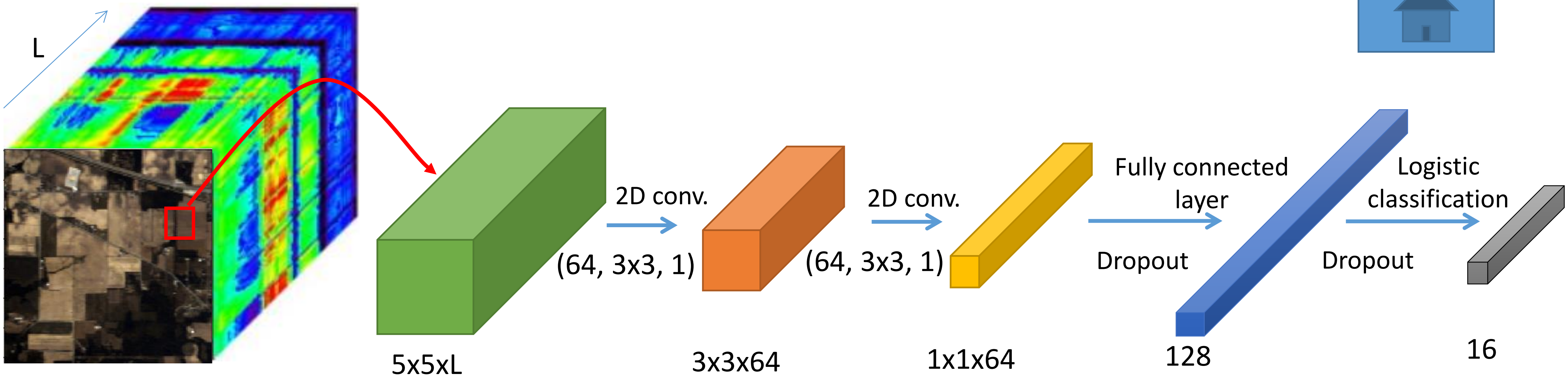
Classification:

2D CNN



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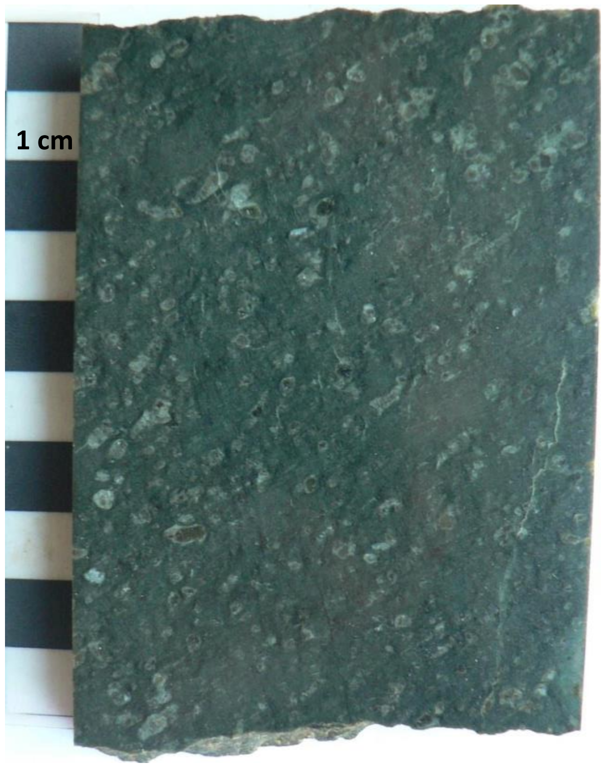
Unmixing results

RGB image



Preprocessed image