Ph.D. thesis proposal

High-dimensional learning for automatic and robust target detection in hyperspectral imagery

Supervisors: Ahmad Bitar (UTT), Alexandre Baussard (UTT)

Starting date: September 2025 (36 months)

Location: Université de Technologie de Troyes (UTT)

Keywords: hyperspectral imagery, target detection, covariance matrix, High-dimensional data, sparsity

Context

The hyperspectral remote sensing system [1] has four main basic parts: (1) the illumination source (e.g. the sun in passive remote sensing); (2) the atmospheric path; (3) the targeted scene; and (4) the airborne hyperspectral imaging sensor. The hyperspectral sensor is able to simultaneously acquiring the same spatial scene in a contiguous and multiple narrow spectral wavelength color bands. When all these spectral bands are stacked together, a hyperspectral data cube with two spatial and one spectral dimensions is obtained. Each pixel of the hyperspectral image follows a specific distribution which is usually completely unknown to the user. Due to the presence of the atmospheric path, the reflected energy (initially captured by the solar illumination and then modified by the atmosphere) from the material surface will be different from the one which reaches the airborne hyperspectral imaging sensor since it passes back through the atmosphere. In this regard, some effects that produce variability to the material spectra (e.g. atmospheric conditions, sensor noise, material composition, scene geometry) have to be taken into consideration.

It is well known that the signal model for hyperspectral test pixels is fundamentally different from the additive model used in radar and communications applications. We can regard each test pixel as being made up of $\alpha \boldsymbol{t} + (1-\alpha)\boldsymbol{b}$, with $0 \leq \alpha \leq 1$, "$\boldsymbol{t}$" the spectrum of the target of interest, and "$\boldsymbol{b}$" the spectrum of the background (located at the same spatial location of $\boldsymbol{t}$). A prior information about the target spectral signature may be available to the user and can be extracted from some online spectral libraries. Different classical target detectors (e.g. matched filter [2], Normalized matched filter [3], matched subspace detector [4], adaptive subspace detector [5]) have been proposed in the literature. The performance of these detectors mainly depend on the estimation quality of the unknown covariance matrix that needs to be estimated very carefully especially in high dimensions and to ensure success under different environments. It is already known that in practice, it is rare to perfectly know the distribution of the data and the Gaussian model assumption is the commonly widely hypothesis used in several applications. The sample covariance matrix [6] is the usual estimator under the Gaussian assumption but is known to be non-robust and to behave badly in large/high dimensions.

Main challenges

In the present Ph.D. project, the shrinkage [7, 8] and sparsity [9, 10, 11, 12] techniques may be exploited to develop new estimators of the covariance matrix in high dimensions in order to achieve a robust target detection in hyperspectral imagery. Due to the lack of real hyperspectral images available online, the Ph.D. candidate will be engaged in generating new hyperspectral images that can help working in some

more realistic scenarios usually encountered in the real world of military target detection. For example: (a) camouflage targets; (b) targets mixed with the background with very low target fill-fraction [10, 11, 12]; (c) targets embedded in a background containing a lot of small heterogeneous and/or high contrast regions [10]; (d) very high spectral dimension; and (e) targets having spectra very close to the surroundings [11, 12]. The latter task is of high importance since the paradigm in military applications for hyperspectral imagery seems to center on finding the target but ignoring all the rest. Sometimes, that rest is important especially if the target is well matched to the surroundings.

To successfully complete this Ph.D. project, the Ph.D. student must be engaged in publishing papers in international conferences and journals.

Candidate profile

- Must have an engineering or master's degree in the fields of signal and image processing.
- Skills are particularly expected in applied mathematics, statistical signal processing, and Matlab programming.
- Experience in hyperspectral or optical imaging would be an advantage.
- An acceptable writing skills in English is highly recommended.

Contract

The Ph.D. position will open in September 2025. The 3 years work will be performed at the Computer Science and Digital Society Laboratory (LIST3N), UTT.

How to apply?

Interested applicants should send a cover letter explaining why they would like to join and a CV to Ahmad Bitar (ahmad.bitar@utt.fr) and Alexandre Baussard (alexandre.baussard@utt.fr), using the line “PhD thesis hyperspectral target detection” in the email title.

The deadline for applying is 30 May 2025.

References

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