Internship proposal: Development of a SPD-autoencoder with time series analysis application for remote sensing data

1 Context and application

In machine learning problems, it is well known that it is unwise to apply classification algorithms directly to large-scale data because of the curse of high dimensionality. To solve this problem, a popular solution is to look for a new data space with a lower dimension, while keeping a good representation of the data. The most common tool is the simple PCA algorithm, which works very well in most applications. Nevertheless, this algorithm can fail, especially when the data is very complex and/or belongs to a large number of classes. Thanks to supervised approaches, new algorithms, known as auto-encoders, have been developed to solve this problem. Numerous architectures have been proposed in recent years, particularly for vector data. There are still architectures to be built, especially when the data are not vectors. In particular, this internship will focus on covariance matrices which have the property of being Symmetric Positive Definite (SPD). Covariance matrices combined with Riemannian geometry [Boumal, 2023] have enabled the development of high-performance machine learning algorithms on EEG [Barachant et al., 2012] or remote sensing data [Collas et al., 2022]. Moreover, these algorithms have shown good robustness in the presence of labeling errors or shits between training and test data.

The application of this internship concerns the analysis of time series from remote sensing data. These data obviously have the characteristics discussed above, in particular they often suffer from large datashifts between training and test (due to strong correlated noise, class variability, ...). In addition, the various frameworks proposed in the literature have shown that covariance matrices are good features for classification. The work will focus on the following datasets [Rußwurm et al., 2020, Sainte Fare Garnot et al., 2022].

2 Objectives

Seminal work has been done to build a deep learning SPD architecture [Li et al., 2017, Huang and Gool, 2017] by developing specific layers for covariance matrices. These networks are based on various Riemannian geometry tools and have shown good performance in computer vision. With the help of these articles, the first task of the internship will be to develop an SPD auto-encoder adapted to covariance matrices.

Our goal is then to develop new learning methods for studying multivariate image time series in remote sensing, more precisely multispectral images containing several frequencies. The main objective of the application is to classify agricultural fields, which is practically impossible without temporal information, as shown in Fig. 1. More specifically, we will adapt the networks used in [Rußwurm et al., 2020] by adding the developed auto-encoder, which should enable to maintain performances with a training set of reduced size.

Finally, we will focus on the dataset [Sainte Fare Garnot et al., 2022], which contains time series of optical and SAR images over the same period. Our goal will then be to adapt the previously developed approach to SAR RADAR data. Indeed, these data are very interesting in that they provide better periodicity and relevant information even at night or in the presence of clouds. However, the properties of SAR images are more complex than those of multispectral images, as they are much noisier and more difficult for non-specialists to analyze.

3 Requirements

Master/Engineering student with knowledge in statistics and machine learning (having followed courses on these topics is strongly advised). Good coding skills in Python.

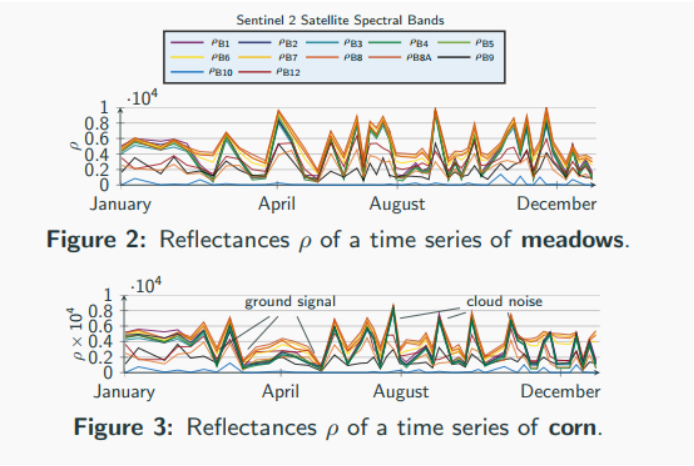

Figure 1: Time series of reflectances of a corn and meadows field. It is easy to see that the spectral information is identical, especially at the beginning of the year. It is the temporal behavior that allows to distinguish them.

4 Internship details:

Location: L2S laboratory in CentraleSupelec, Paris and/or LISTIC laboratory in Univ. Savoie Mont-Blanc, Annecy.

Duration: 4-6 months

Context: This work will constitute the beginning of a collaboration between Univ. Savoie Mont-Blanc, CentraleSupelec and Univ Aix Marseille.

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