Research results 2014–2018

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1 High-dimensional and structured data

1.1 Scientific achievements

Classification in high dimension. We extended our work on high dimensional classification and clustering (Gaussian HDDA and HDDC methods) along two main lines: 1) by combining the parsimonious covariance representation in HDDA and HDDC with kernel methods so as to tackle nonlinear and non continuous data (joint work with C. Bouveyron, Univ. Paris and M. Fauvel, Univ. Toulouse) [6]; 2) by being able to deal with qualitative and discrete data (PhD thesis of S. N. Sylla Univ. Gaston Berger, St Louis, Senegal [4], applied to verbal autopsy data in order to assess the population-level causes of death in Senegal) [32].
Regression in high dimension. Another issue occurring with very high dimensional data and typically with hyperspectral images (several hundreds of spectral bands) is that data storage becomes impossible and the computational load also dramatically increases. To overcome these limitations, we proposed (PhD thesis of A. Chiancone in collaboration with the Gipsa-Lab [1]) to develop sequential (or on-line) dimension reduction methods [9]. We also studied the possibility to adapt inverse regression techniques such as SIR to more general settings including data streams [7], multivariate responses [10] and non Gaussian data [8].
Structure learning. We investigated the use of copulas to characterize the dependence structure in data during the PhD of G. Mazo [3]. First, we considered factor models to reduce the complexity of the model to estimate [29]. Then, we considered graphical models to account for the dependence structure and provide keys to efficient inference algorithms using the idea of cumulative distribution networks (CDN) [27]. Robust general estimation of copulas was addressed in [28] while specific copulas models have been investigated in [5, 14].

1.2 Collaborations

The work on classification was joint with C. Bouveyron (Univ. Paris 5, now at Univ. Nice), M. Fauvel from INRA team DYNAFOR in Toulouse, in the context of M. Lopes's PhD thesis [2] and S. Iovleff MODAL through the CloHe project. The work on SIR was joint with Gipsa-lab (A. Chiancone's PhD) on one hand and with CQFD team on the other hand. Applications to astrophysics were conducted in collaboration with D. Fraix-Burnet (IPAG) [68, 80, 82] and V. Watson (IRAP) [62]. The PhD of S. Sylla was co-supervised with Univ. Gaston Berger in Senegal. We also collaborated with F. Durante (Univ. Salento, Lecce, Italy) on copula modelling [75, 14].

2 Extreme value modelling

2.1 Scientific achievements

One of the main issues in extreme-value analysis is to attach a risk measure to extreme events, *i.e.* located in the distribution tails. The most used risk measure is the Value-at-Risk (VaR) in finance. From a statistical point of view it can be interpreted as an extreme quantile, that is a quantile of order $\alpha_n \to 0$ as the sample size $n \to \infty$. The VaR is also refered to as the return level in environmental contexts. Despite its popularity, the VaR suffers from several drawbacks: 1) It is not a coherent risk measure, meaning that it does not enjoy the subadditivity property; 2) It is a local measure of risk which does not take into account the whole distribution tail; 3) It is limited to unidimensional events. Our objective is thus to introduce new extreme risk measures which do not suffer from these limitations.

Multivariate risk measures. A univariate quantile can be interpreted as the solution of a univariate L_1 optimization problem. Some authors have proposed new multivariate quantiles (called geometric quantiles) as the solutions of a similar but multivariate optimization problem. We have proved [22, 23] that this definition yields very un-natural properties from an extreme point of view and therefore that geometric quantiles should not be used as multivariate risk measures.

Univariate risk measures. As an alternative to the above mentioned L_1 optimization problem, one could consider more general L_p norms, $p \geq 1$. This gives rise to the notion of L_p- quantile also known as expectile in the particular case $p = 2$. This generalization opens the door to a wide class of new risk measures with better properties than the usual VaR [12, 13]. Even more generally, any risk measure based on the VaR (Conditional Tail Moment, Expected Shortfall, ...) can be adapted to this new framework.

Conditional risk measures. In many cases, the phenomenon of interest depends on additional factors and thus the tail heaviness, the extreme quantiles, and more generally any risk measure associated with the variable under consideration may depend on a number of covariates. For instance, in climatology, one is interested in how climate change over years might affect extreme temperatures or rainfalls. In this case, the covariate is univariate (time). Bivariate examples include the study of extreme rainfalls as a function of the geographical location. The estimation of risk measures depending on covariates is an important addition to the standard theory: it is based both on extreme-value analysis and nonparametric smoothing methods [15, 16, 17, 19, 20, 77]. Interestingly, the recurrent problem of boundary/frontier estimation can be embedded in this framework of conditional extreme-value analysis. The frontier is interpreted as the endpoint of a conditional distribution and new estimation methods can be proposed [11, 21, 30].

2.2 Collaborations

Our theoretical work on extreme-value analysis is done in collaboration with A. Daouia (Univ. Toulouse), J. Elmethni (Univ. Paris-Descartes), L. Gardes & A. Guillou (Univ. Strasbourg), A. Nazin (Univ. Moscou, Russia) and G. Stupfer (Univ. of Nottingham, UK). The joint work with E. Deme (Univ. Saint Louis, Senegal) [74] is achieved in the context of the SIMERGE associate team. Applications to environmental risk were conducted in collaboration with M. Stehlik (Univ. Johannes Kepler, Linz, Austria) [24, 31] and B. Barroca (Univ. Paris-Est) [5]. An application of extreme-value statistics to intrinsic dimension estimation was performed in collaboration with the former TEXMEX Inria team (Rennes) [53].

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