

RESEARCH MASTER INTERNSHIP

Department of Complex Systems Engineering

Location : Toulouse, campus SUPAERO

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INTERNSHIP DESCRIPTION

Domain : **APPLIED MATHEMATICS**

Title: **MODELLING AND SIMULATION OF EXTREME EVENTS USING GENERATIVE MODELS**

Fields: Statistics, Extremes, Machine Learning, Multifidelity

Research activities

Modern generative models (normalizing flows, GANs, diffusion models) have recently transformed the field of statistical learning by enabling the generation and approximation of complex high-dimensional distributions. These methods have found numerous applications in computer vision, signal processing, and physical simulation. However, these approaches remain largely focused on the bulk of the data. Regions of extremely low probability, corresponding to rare and intense events, remain poorly represented. Yet these events are precisely the subject of Extreme Value Theory (EVT), a branch of statistics dedicated to the study of distribution tails.

Conversely, EVT provides a robust mathematical framework for modeling and extrapolating tail behavior. However, it suffers from significant limitations: the rarity of extreme observations and the curse of dimensionality make its application challenging as soon as more than two or three variables are considered. In fields such as aeronautics, energy, and finance, the need to accurately estimate joint extreme risks therefore makes the development of new hybrid methods essential.

The objective of this internship is to study how to modify the training of generative models (normalizing flows, diffusion models) so that they respect the asymptotic constraints of EVT and are capable of simulating samples that adhere to a given extreme dependence structure. This includes incorporating theoretical knowledge (regular variation, tail indices, angular measure) into the architectures or loss functions, as well as developing weighted learning schemes that focus attention on rare observations.

Bibliography

- Asghar, S., Pei, Q. X., Volpe, G., Ni, R. (2024). Efficient rare event sampling with unsupervised normalizing flows. *Nature Machine Intelligence*, 6(11), 1370-1381.
- L. Rudi, A. Ghosal, A. Kroese. Generative models for rare event simulation. *Annals of Applied Probability*, 2023.
- McDonald, A., Tan, P. N., Luo, L. (2022). Comet flows: Towards generative modeling of multivariate extremes and tail dependence. [arXiv preprint](#).

Application: please send us by email a curriculum vitae.

Application deadline: end of February 2025.
Location: ISAE 1, Campus SUPAERO (Toulouse, France).
Duration: 5 months, starting March or April, 2025.

50 % Theoretical Research	50 % Applied Research	0 % Experimental Research
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Possibility to go on a Ph.D.: ☐ Yes

APPLICANT PROFILE

Knowledge and required level:

Statistics (Master)

Programing Python.

Applications should be sent by e-mail to the supervisor.