Master internship and PhD thesis offers on *Gaussian process modeling of mechanical random fields: a complete study from simulation to identification*

General context. A contemporary avenue to modeling practical systems involves blending machine learning (ML) techniques with physics-based models. Within the framework of the ANR JCJC GAME project [1], both the master internship and PhD thesis seek to actively contribute to advancing this scientific trend by leveraging Gaussian processes (GPs) as the chosen probabilistic ML technique. GPs excel as generative models, seamlessly incorporating physics knowledge into the modeling process [2]. The guiding research principles are to study simulation and identification settings in mechanical applications involving expensive computer codes, and to push the boundaries of current GP models and ML algorithmic procedures.

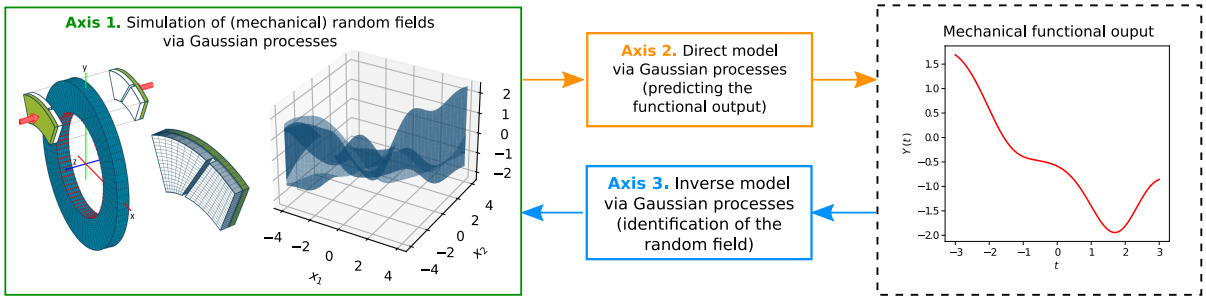

Figure 1: General framework proposed in the ANR JCJC GAME project for an automotive application.

• Physically-inspired kernel designs for GPs. Due to their computational complexity, GPs are limited to moderate datasets (in the order of hundreds or thousands of observations). This limitation may prevent models from capturing the dynamics of fields in situations where physical constraints are encountered [3]. The same effect can be found in experiments where data are scarce (e.g. in composites manufacturing [4]). In both cases, physically-inspired expert knowledge needs to be encoded into kernels to improve the predictability of GPs.
• Parameter identification. Besides the importance of parameter identification, inverse problems involving complex systems are usually challenging or ill-posed. In mechanics, it is often assumed that simulations can be performed within a tractable time with the help of HPC. However, this is not always feasible and other types of methodologies must be further explored. In GAME, we seek to use physically-inspired GPs for emulating mechanical computer codes. These GP-based emulators will allow the generation of a large number of virtual experiments that can be processed to characterize other mechanical random events via ML techniques.

Objectives of the master internship and PhD thesis. The main objective of the master internship is to design kernels for simulating random fields in one of the following applications:

- Spatial flows in porous media [4].
- Wear topographies in brake systems [5].

The main objectives of the PhD thesis are:

1. To design kernels for simulating random fields in the above applications (Axis 1).
2. To build GP models with functional inputs and functional outputs (Axis 2) [6, 7, 8]
3. To investigate identification frameworks for the aforementioned GP models (Axis 3).

Expected research outputs. One expect to significantly improve the accuracy of the current (often deterministic) ML models and algorithms by using both probabilistic frameworks based on GPs and adapted kernel designs accounting for physical information or functional data. The output is methodological and will lead to publications in international journals in applied mathematics, mechanics and/or leading conferences in machine learning.

Organizational details and supervising team. The master internship is funded for 6 months and will start in Spring 2024. Depending on the outputs of the internship, there is the possibility of continuing with the PhD. The PhD thesis is funded for 3 years and will start in Fall 2024. For a candidate already holding a master's degree, the PhD training can start as soon as possible.

Both the master internship and PhD will be supervised by a strong and well-balanced team with experts on stochastic processes, Gaussian processes with application in mechanics.

- Julien Bruchon, Professor at Mines Saint-Étienne (EMSE), France [bruchon@emse.fr]
- Rodolphe Le Riche, CNRS senior researcher (HDR), EMSE, France [leriche@emse.fr]
- Andrés F. Lopéz-Lopera, Associate Professor at Université Polytechnique Hauts-de-France (UPHF), France [andres.lopezlopera@uphf.fr]
- Franck Massa, Professor at UPHF, France [franck.massa@uphf.fr]

The positions will be located at UPHF. Research visits to EMSE during the PhD are planned and will be funded by the GAME project. Collaborations with other members of the project are encouraged.

How to apply? Applications are considered until the positions are filled. The candidates should have master-level skills in mathematics, statistics or machine learning. Outstanding Python or R programming skills will be appreciated. Please send a CV (in English or French), application letter and grade transcripts (bachelor and master level) to the supervising team.

References related to the PhD subject.

[1] A. F. López-Lopera, J. Bruchon, R. Le Riche, F., Massa, I. Massa-Turpin, and L. Reding, *ANR JCJC GAME – GAussian process modeling of transient MEchanical random fields: A complete study from simulation to identification*, 2023 – 2027. [Online]. Available: https://anfelopera.github.io/funding/GAME/

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[3] A. F. López-Lopera, N. Durrande, and M. Álvarez, "Physically-inspired Gaussian process models for post-transcriptional regulation in Drosophila," *IEEE/ACM Transaction on Computational Biology and Bioinformatics*, vol. 18, no. 2, pp. 656–666, 2021.

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[7] A. F. López-Lopera, F. Massa, I. Turpin, and N. Leconte, "Modeling complex mechanical computer codes with functional input via Gaussian processes," in *The XLIII Ibero-Latin American Congress on Computational Methods in Engineering (CILAMCE)*, 2022.

[8] L. Reding, A. F. López-Lopera, and F. Bachoc, "Asymptotic analysis for covariance parameter estimation of Gaussian processes with functional inputs," *Work in progress*, 2023.