PhD offer:
High-dimensional optimization of the internal and external aerodynamics of a vehicle

Period: October 2016 - October 2019
Location: Saint-Etienne, frequent stays in the Paris and Toulouse areas.

Funding:

- CIFRE Groupe PSA (Industrial Agreement for Training through Research) - The CIFRE fellow will sign a 3 years full time work contract with Groupe PSA.
- Year gross salary: of the order of 30Keuros.

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Applicant Profile: Candidates should have completed a Master in applied mathematics, statistics, machine learning, or engineering with a mathematical background. The applicant should demonstrate both theoretical and computational skills. Implementations in R are expected.

Context: Committed to reducing the fuel consumption and emissions of its vehicles, Groupe PSA innovates continuously to develop ever cleaner and energy-efficient models. As an integral part of its advanced research process for developing new engines and external aerodynamics solutions, Groupe PSA has been using 3D numerical simulations for many years.
To handle both complexity of the phenomena that occurs in these simulations and optimization of antagonist objectives, multi-criteria optimization methods are needed.

Objectives of the PhD: The objective of this PhD is to devise and validate a multi-objective optimization method of 3D aerodynamic simulations. In this context, optimization problems are particularly challenging to tackle, due to the non-linearity of the simulation outputs, the computational cost of a single simulation (from 12 hours to three days), the need to handle complex constraints, or the large number of parameters to optimize over (20 to 40 unknowns).

Recent approaches based on Gaussian processes have shown promising results, but address this problem only in part: see [1,2,3,4] for examples. Projections in subspaces have been proposed to handle large number of unknowns [5]. For this PhD, the investigated methodology will follow this line of work, and will focus in particular on:

- efficient sampling strategy in the presence of several objectives and constraints,
- an automated reduction in dimension in order to deal with many unknowns with a restricted number of simulations,
- the possibility to distribute calculations in an asynchronous fashion on about 10 computing nodes, and
- dealing with the event of simulation failures.

The approach developed will be validated on two industrial cases dealing with shape optimization:

- optimization of the chamber design of an internal combustion engine,
- optimization of the external shape of a vehicle [6,7,8].

In these cases, the unknowns are design parameters (via CAD tools), and drag coefficient or combustion efficiency are examples of objectives and constraints. The method will be programmed in the R language.

Bibliography

[1] M. Binois and V. Picheny, "GPareto: An R Package for Gaussian-Process Based Multi-Objective Optimization and Analysis", 2016, https://cran.r-project.org/web/packages/GPareto/vignettes/GPareto_vignette.pdf

[2] V. Picheny, "Multiobjective optimization using Gaussian process emulators via stepwise uncertainty reduction", Statistics and Computing, Volume 25, Issue 6, pp. 1265-1280, 2015

[3] Paul Feliot, Julien Bect, Emmanuel Vazquez, "A Bayesian approach to constrained single- and multi-objective optimization", Learning and Intelligent Optimization: 9th International Conference, LION 9, Lille, France, 2015

[4] Wagner, Tobias, et al. "On expected-improvement criteria for model-based multi-objective optimization." Parallel Problem Solving from Nature, PPSN XI. Springer Berlin Heidelberg, 2010. 718-727.

[5] Z. Wang, M. Zoghi, F. Hutter, D. Matheson and N. De Freitas, "Bayesian Optimization in High Dimensions via Random Embeddings", IJCAI conf., 2013.

[6] L. Cui, T. Wang, Z. Lu, M. Jia and Y. Sun, "Full-Parameter Approach for the Intake Port Design of a Four-Valve Direct-Injection Gasoline Engine". ASME. *J. Eng. Gas Turbines Power.* 2015;137(9).

[7] M. Yagoubi, L. Thobois, M. Schoenauer, "An asynchronous steady-state NSGA-II algorithm for multi-objective optimization of Diesel combustion", Int. Conference of Engineering Optimization, 2010.

[8] John B. Heywood. "Internal Combustion Engine Fundamentals". *McGraw-Hill*, 1988.