Global multi-objective high-dimensional optimization for automobile design

Starting date: October 2012
Location: Ecole des Mines de St-Etienne, with stays at the University of Bern (Switzerland) and Renault, Guyancourt, France.
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General context

The objective of the car design process is to determine in a limited time the technical definition of a vehicle that meets cost, mass, performance (e.g. gas efficiency, crash safety, etc.) requirements compatible with the clients needs. Today, the design optimization is based on computer simulation and its ability to assess the quality of solutions. Modern computer codes are more and more efficient in predicting the behavior of structures, but also more and more expensive to evaluate. Therefore, efficient optimization techniques are essential to keep up with accelerating development cycles.

The EGO method (Efficient Global Optimization, [Jones, Schonlau, Welch, 1998]) is known to be one of the most relevant optimization techniques for the exploitation of time-consuming computer codes. Intrinsically linked to the construction of a cheaper stochastic (meta-)model of the computer code, the EGO algorithms uses the corresponding probabilistic information to alternate cleverly between local and global search. Technically, EGO is based on specific spatial random processes, often called Kriging models, and on the so-called "Expected Improvement" criterion. During a previous scientific project ("DICE" project) involving the partners of this PhD program, D. Ginsbourger investigated the potentialities of the EGO method, and a R package was developed with O. Roustant, with successful applications to small (≤10) dimensional problems. On the industrial side, the interest of the approach is to provide an integrated solution (metamodel + optimization) that can provide better solutions for a given computational budget.

Objectives of the Ph.D. work

The goal is to optimize a vehicle for crashworthiness, based on high-fidelity finite element models. Each evaluation of the computer code is very expensive (several hours on a supercomputer) and can be noisy. We want to determine in the most effective manner the shape, material, thickness of each of the vehicle structure components in order to optimize the mass/crash trade-off.

The objective of the Ph.D. work is to extend the EGO optimization algorithm in order to make it suitable for industrial applications. More specifically, it is expected to lay out appropriate strategies to deal with the following difficulties:

1. the large number of design variables considered (10-100) make existing techniques inapplicable,
2. industrial applications include design constraints (ex. limits on displacements, etc.) and are inherently multi-objective. These aspects are only partially covered in existing methods.

The outcome of this work is both methodological and applicative. We expect:

1. a contribution to high-dimensional global optimization, in a multi-objective context
2. the application of the EGO algorithm to industrial vehicle optimization problems, and the assessment of its benefits compared to traditional approaches
3. an implementation of the developed algorithms in R packages

Work schedule (guidelines)

[Oct. 2012 – Apr. 2013]	Bibliography on global optimization, EGO, multi-objective optimization based on Kriging metamodels, high-dimensional optimization.
[Nov. 2012 – Jan. 2013]	Formulation of the industrial test case
[Jan. 2013 – Oct. 2013]	Implementation of the simulations for the industrial test case.
[Feb. 2013 – Dec. 2013]	Proposition of a first method and academic tests.
[Jan. 2014 – Jun 2014]	Analysis of first experience and industrial application.
[Jul. 2014 – Dec. 2014]	Proposition of a second approach and academic tests.
[Jan. 2015 – May 2015]	Industrial application of the second method.
[Jun. 2015 - Sept. 2015]	Manuscript write-up.

Candidate profile

The candidate should have a background in applied mathematics or mechanical engineering with a strong taste for mathematics. Skills and clear motivation for computer implementation are also necessary. An interest in automobile applications will be appreciated.