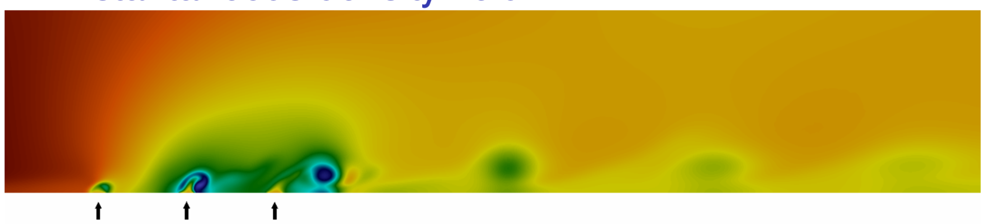
Multi-point optimization of a system of pulsating jets in a time-periodic compressible Navier-Stokes flow

An instantaneous density field



Physical model: time-periodic compressible Navier-Stokes flow over a flat plate in laminar regime subject to three pulsating jets of amplitudes and phases to be optimized (6 parameters) to enhance flow mixing and reduce drag.

Optimization objective: to reduce the time-periodic drag force $\mathbf{D}(t)$ ($t \in [0, T]$).

Method: Multiple Gradient Descent Algorithm (MGDA) applied to the K gradients of the time discretized drag, $\{\nabla\mathbf{D}(t_1), \nabla\mathbf{D}(t_2), ..., \nabla\mathbf{D}(t_K)\}$ ($K = 800$) in which the K instantaneous gradients $\{\nabla\mathbf{D}(t_k)\}$ are calculated w.r.t. the 6 jet parameters and evaluated by solving the sensitivity PDE system as part of the integration timestepping.

Result: Every application of MGDA has the effect to diminish *all* instantaneous drag forces $\{\mathbf{D}(t_k)\}$. This would not have been the case in a more classical approach consisting of minimizing the mean drag, $\int_0^T \mathbf{D}(t)\, dt$ by a descent method.

Ref.: Parametric optimization of pulsating jets in unsteady flow by Multiple-Gradient Descent Algorithm (MGDA), J.-A. Désidéri and R. Duvigneau. In: *Numerical Methods for Differential Equations, Optimization, and Technological Problems, Modeling, Simulation and Optimization for Science and Technology,* J. Périaux et al. eds. (2017). `https://hal.inria.fr/hal-01414741`

This exercise has demonstrated:

- **the accuracy of gradients calculated by the sensitivity equations, and**
- **the potential of MGDA as a descent method applicable to a large number of gradients (800).**

Furthermore, it offers a variety of possibilities for the optimization of time-dependent systems, as an alternative to the classical approach of functional minimization.