

The optimization group

The optimization group of the CTR summer program focused on the development and implementation of novel deterministic and stochastic optimization techniques to the design of micro-fluidic channels and to the destruction of trailing aircraft vortices. The CTR summer program was instrumental in facilitating, for the first time, the close interaction of scientists working in the areas of deterministic and stochastic optimization, allowing a critical assessment of both techniques and opening new areas for collaborative, interdisciplinary research.

The optimization of microfluidic channels used in bioanalytical applications served as a common testbed for the application of novel optimization techniques. Mohammadi, Molho and Santiago implemented a dynamic minimization technique developed by Mohammadi and Pironneau (2000) and conducted an extensive study of the optimization of the geometry of these channels in a CAD-free framework. Their results revealed an array of novel efficient designs for serpentine channels with 90 and 180 degree turns. Moreover, the study of this group demonstrated how advanced optimization techniques developed for the needs of aerodynamic applications can transcend and impact domains such as those of microfluidics.

In parallel, Sbalzarini, Müller and Koumoutsakos developed and implemented evolution strategies with step size adaptation and in parallel computer architectures for a class of microfluidic channels with 90-degree turns. They obtained a series for designs encompassing the optimal results obtained by the deterministic schemes, albeit at higher computational cost. An additional purpose of this group study was the development of novel evolutionary multi-objective optimization strategies. These studies resulted in an array of designs compensating between manufacturing costs and minimal dispersion.

The portability for evolutionary algorithms allowed for another study by Cottet, Koumoutsakos and Sbalzarini on the destruction of trailing aircraft vortices. Using fast, viscous vortex methods and a set of vortices modeling the wake of airplanes at landing configurations, evolution algorithms recovered in an automated optimization cycle the results found by linear stability theory (Crouch, 1997). Moreover, novel vortical arrangements were revealed that allow for larger distortion of the tip vortices.

In summary, this CTR summer program laid the foundation for a critical assessment of various optimization techniques while demonstrating the interdisciplinary character of the developed optimization tools. A preliminary conclusion of this study is that deterministic optimization techniques are the method of choice for well defined problems where gradient information is readily available. However, this information may come at the expense of linearizations and constrained parameterizations of the problem. Evolutionary algorithms circumvent these difficulties at the expense of higher computational cost. An additional difficulty with evolutionary techniques is the absence of rigorous results regarding their convergence. On the other hand evolutionary algorithms are robust, embarrassingly parallel and highly portable algorithms that may make them the method of choice in certain engineering problems. We hope that the works of this CTR Summer Program would serve in initiating further interactions between researchers in deterministic and stochastic optimization as applied to a wide range of interdisciplinary engineering problems.

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