A Greek Success Story in ‘Aerodynamic Shape Optimisation’

SUCCESS STORY IN AERODYNAMIC SHAPE OPTIMIZATION (Greece)

COMPANY: Grammarios Bikes

Grammarios Bikes is a Greek SME focusing on building, maintaining and optimizing custom made bicycles.

THE PROBLEM

Design a bicycle with a lower drag and side force than the baseline one, evaluated at four different operating conditions.

SUCCESS STORY DETAILS
HPC provider: ARIS GRNET
Domain Expert: PCOPt/NTUA
Country :Greece
Link:
http://velos0.ltt.mech.ntua.gr/research/index.html

THE HPC PROBLEM DOMAIN

The HPC problem domain falls within CFD-based aerodynamic optimization.

An algorithm should be devised that automatically evaluates and optimizes bicycle geometries, given the chosen objective functions (here aerodynamic drag and side forces).

THE SOLUTION

An automated shape optimization was performed using an adjoint-assisted, gradient-based optimization algorithm.

THE BENEFITS

- Small turnaround times
- No trial-and-error schemes: the algorithm should always come up with a better solution than the previous one

Design inspiration NCC Austria

EURO

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THE PROBLEM

A client of "Grammarios Bikes asked for a custom-made bicycle with lower drag and side forces than the one he owned. Specifically, the new bicycle should perform better than the current one in a range of bicycle and side wind velocities. The combination of these requirements gave rise to a multi-point, multi-objective aerodynamic optimization problem.

THE HPC PROBLEM DOMAIN

Each bicycle geometry needs to be evaluated at four different operating conditions, using a state-of-the-art Computational Fluid Dynamics (CFD) solver, on a mesh consisting of 7.5 M cells and using 100 CPU cores. The cost of such an evaluation is around 200 CPU-hours.

Since the evaluation of each candidate geometry has a non-negligible CPU cost, an optimization algorithm that can design the optimal bicycle geometry within a relatively small number of optimization cycles and a robust HPC system are required.

THE SOLUTION

An adjoint-assisted, gradient-based optimization algorithm was used to solve the aforementioned problem. In specific, the *adjointOptimisationFoam* s/w, developed by PCOpt/NTUA and made publicly available through the open-source CFD toolbox, OpenFOAM, was utilized.

The two objective functions from the four operating points were concatenated into one, using weights provided by the end user, based on how frequent each of the operating point was. Each optimization cycle had a cost of about 400 CPU-hours, requiring the solution of four flow and adjoint systems and the overall cost was 4500 CPU-hours (11 opt. cycles)

THE BENEFITS

The utilization of an adjoint-based optimization algorithm led to a low number of optimization cycles and, thus, a relatively short turnaround optimization time (less than 48 hours when ran on 100 CPU cores).

Aerodynamic drag was reduced in all operating points (from 2% to 3.9%, depending on the point) while keeping the side force almost intact. This result was achieved by redesigning the front fairing, which was enlarged, and the front and rear wheel rims, with an emphasis on the former which had its inner radius and spokes width increased.

All the above where done without building different bicycle geometries and resorting to experiments, saving up time and resources.

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