Optimization of bio-inspired bluff bodies using innovative Artificial Intelligence (AI)

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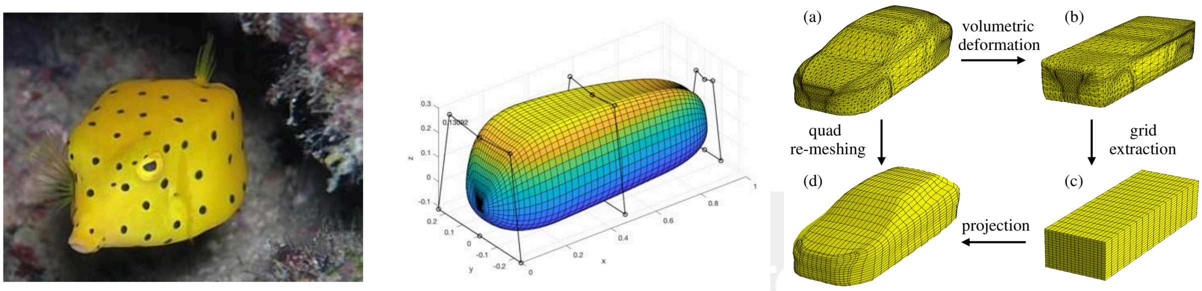

Context and objectives:

Nowadays, improving the efficiency of air and ground mobility systems is required to reduce greenhouse gas emissions as well as air pollution. To achieve a significant reduction of these drawbacks, real breakthrough is mandatory, which calls for innovative methods to design and optimize these shapes which are essentially bluff-bodies operating under large drag forces. In nature, Boxfishes (left in the figure) can achieve high velocities (5 body length per second) with a very low drag coefficient: $C_D = 0.13$ for $Re=10^4$-10^5. This is impressive for a box-like body [1], since best modern cars perform around $C_D = 0.3$ *for* $Re = 10^7$.

To propose novel vehicle shapes, bio-inspired geometries are often combined with Computational Fluid Dynamics (CFD) and optimization procedures. Yet, because CFD is expansive for large Reynolds number flows, classical optimization methods are limited to a few computations, reducing the potential breakthrough of finding innovative shapes: optimization is often restricted to a few geometrical parameters (middle in the figure). To explore new geometries, novel optimization techniques should be developed. Recently, Artificial Intelligence (AI) came into the play, demonstrating outstanding results. AI-assisted optimization usually relies on training Convolutional Neural Networks (CNN) on GPUs with image-like structured data. When using CFD 3D unstructured data, *(i)* CNN efficiency drops and *(ii)* memory problems appear. Baque et al. [2] proposed in 2018 a method to comply with these two objectives: the geodesic convolutional shape optimization (right in the figure). It allows an efficiency optimization by focusing on the 2D skin instead of the complete 3D fields, limiting then the memory needed. Moreover, a key to making this approach practical is remeshing the original shape using a poly-cube map (structured data), which makes it possible to perform the computations on fast GPUs instead of slow CPUs.

The objective of this research project is to understand and develop the Geodesic Convolutional method proposed by Baque et al., to be used for future optimization studies at DAEP. Once coded and tested, this approach will be applied by the student on the optimization of a boxfish-like configuration, also studied in a companion research project where CFD simulations and experiments will be carried out by 2 other students. The optimization will be done on the brand-new AI-dedicated GPUs available on the ISAE-Supaero's supercomputer. The candidate will be part of a small team at DAEP focusing on the boxfish configurations and optimization methods. The student might be also involved in the other AI activities conducted at DAEP.

[1] Summers A. (2005) Boxed up to go. Nat. Hist. ***114****, 38–39*

[2] Baque P. (2018) arXiv:1802.04016v1